HYDRO - ELECTRIC DEVELOPMENT ON NORTH PLATTE RIVER WYOMING

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Proposed hydro-electric
development on North Platte

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PROPOSED HYDRO-ELECTRIC DEVELOPMENT

IN

NORTH PLATTE RIVER WYOMING

A THESIS

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DESIGN OF A HYDRO-ELECTRIC PLANT.

PREFACE.

This thesis will cover the general plans of power house, terminal station, dam, transmission line and pipe line, for a hydro-electric plant with an ultimate capacity of 50,000 generated horsepower.

No attempt will be made to develop any of the formulae used in this design or to design the details for the machinery which is specified. As nearly as possible, the latest practice in stations of this type will be followed, no attempt being made to secure original design where standard machinery could be used.

The field for the sale of power for this station is not yet fully developed and for this reason it was thought wise to secure the most economical construction and apparatus consistent with the reliability of service which would be demanded.

The data available, at the time of

making these plans,was not as complete as was desired and for this reason it may be thought advisable to make some minor changes in the details before the construction of the plant, but it is intended that there shall be no material deviation from the plans as outlined, in the following pages.

The discussion of the plans will be given under the heads listed below. Only the reasons for the choice of apparatus and the formulae directly applied to calculations will be given in this discussion.

1. General information on location, water-flow and topography.
2. Design of Dam.
3. Design of Power House.
4. Design of Terminal Station.
5. Design of Transmission Line.
6. Design of Pipe Line.
7. General Estimation of Cost.

GENERAL INFORMATION ON LOCATION, WATER-FLOW, AND TOPOGRAPHY.

The proposed development is located in Carbon County, in the south central part of Wyoming, about twenty-five miles northeast of Rawlins, near the junction of the Medicine Bow River with the North Platte River.

Source Of Water Supply;-

The water supply for this development will be obtained by impounding the waters of the North Platte River and its tributaries at the point where the river flows through the canyon in the Seminole Range. From this point the water will be led to the power house, through a pipe line which will be approximately two miles long.

Stream Measurement;-

There was no data available for this exact location in regard to stream flow or maximum discharge, so it was necessary to use the government reports obtained at the stations, Alcova and Saratoga, located on the North Platte River, the former below this

development and the latter above. The data obtained at Alcova was used as the basis for calculations for the Pathfinder Project which is about thirty-five miles north. The water flowing into the Pathfinder Dam must come from the same source as the water used in this development with the exception of the water supplied by the Sweetwater River,which empties into the North Platte below this development. The quantity,furnished by this river was subtracted from the total flow at Alcova and the resulting flow was used as the basis for the calculations. Tables of the water flow for the years 1904,1905 and 1906,taken by the government at the two above mentioned stations, are given below. Theses tables give the monthly discharge during each month,and also the mean and minimum values of flow in acre feet.

Drainage Area;-

The drainage area of the North Platte River,above the Seminole Power Site,

Location, Water Flow and Topography.

Estimated monthly discharge of North Platte River at Alcova and Pathfinder.

Month	1904	1905	1906	Mean	Minimum
Jan.	#19030	#25170	#14230	22100	14230
Feb.	#17190	#22730	11580	19960	11580
Mar.	#19030	#25170	48890	22100	19030
April	102900	82950	178860	92925	82950
May	362800	289400	372740	326100	289400
June	412100	526900	429440	464500	402100
July	111200	111700	130240	111450	111200
Aug.	35790	35290	17840	35540	17840
Sept.	25150	16240	18100	19695	18100
Oct.	29640	21340	13940	25490	13940
Nov.	#18420	24160	19820	21290	19820
Dec.	#19030	#25170	14230	22100	14230
	1160280,	1206220	1269910	1183250	1014420

quantities supplied to complete yearly record.

This table is compiled from the records published in U.S.G.S. Water Supply and Irrigation Papers Nos. 131, 171, 208.

Location, Water Flow and Topography.

Esimated Monthly discharge of North Platte River at Saratoga.

Month	1904	1905	1906	Mean	
Jan.	20660	21330	28520	20995	20660
Feb.	18820	19270	25760	19045	18820
Mar.	36160	26160	28520	31145	26130
April	88070	56650	99400	72360	56650
May	295900	204700	291000	250300	204700
June	320400	417700	337000	369050	320400
July	82390	86330	123000	84360	82390
Aug.	30680	26440	33400	28560	26440
Sept.	19760	13450	29900	16605	13450
Oct.	23060	18380	28300	20720	18380
Nov.	15140	19870	27600	17640	15410
Dec.	12920	21330	28520	17125	12920
		964230	931580	947905	816350

This table is compiled from records published in U.S.G.S. Water Supply and Irrigation Papers Nos. 121, 171, 208.

Location, Water Flow and Topography.

approximates 8,500 square miles.

Precipitation;-

This development is located in a mountainous and dry country and for this reason the precipitation is variable over the various districts. This variation is between 9 and 30 inches although no record has been kept of the higher mountion area, the precipitation probably runs as high as 40 inches in some places. The mean precipitation for the entire area is about 16 inches as a safe figure, for the drainage basin south of the Seminole Range.

Run-Off;-

From the detailed results of the run-off measurements, it appears that each square mile of the drainage basin south of the Seminole Mountains should furnish an average of 130 acre feet of water. This would make a total run-off average of 1,105,000 acre feet per year.

Elevation and Climate;-

The elevation of the power site

above the sea level is approximately 6,300 feet. The mean annual temperature is approximately 44° Farenheit with extremes of minus 30° in the winter to 103° in summer.

DESIGN OF DAM.

The reservoir required to impound the necessary amount of water is to be secured by building a dam 170 feet high, in the canyon formed by the North Platte River in the Seminole Range.

The reliability of the entire project depends on the stability of this dam, not only as to continuity of service but also as to the safety of the entire financial investment. For this reason, an endeavor was made to secure a dam structure which would be practically indestructible by the agents commonly considered in engineering practice, and which would still be economical of material.

After a consideration of the various types of dams, it was decided that the gravity type was the better type for this development. Because of the height, the earth filled dam could not be considered and for the same reason and also be cause of the length required it did not seem ad-

Design of Dam.

visable to consider the hollow,steel-concrete type of construction which has been used of late for some successful devel opments with lower heads. The true arch type of dam was considered but there did not seem to be any great difference in the cost of construction of the arch type and the gravity type due to the fact that greater care would be required in selecting and shaping the material,and in the building of the dam. Since it is expected that all of the stone can be quarried from the immediate neighborhood,the principal cost of this material will be in the labor. The arch type of dam has not been thoroughly tested as yet in a dam of this size,and its reliability is rather an uncertain quantity.

There are a great many methods available by which the profile of the dam can be determined. From these methods, Wegmanns analytical method was chosen because of the fact that it secures as econom-

Design of Dam.

ical a profile as is consistent with the other requirements,and because a number of successful gravity dams of considerable magnitude, have been constructed with this method as a basis.

In the following discussion;-

"Front",will signify "down-stream".

"Back",will signify "up-stream".

P denotes line of pressure,reservior full.

P'denotes line of pressure,reservoir empty.

The unit of weight will be one cubic foot of masonary. (143.75 pounds/cubic foot)

All linear dimensions infeet.

a is top width of dam.

x is unknown length of a joint of masonary.

l is a known length of a joint above x.

h is the depth of a course of masonary.

u is distance of P from front edge of x.

n is distance of P'from back edge of x.

m is distance of P'from back edge of l.

v is distance between P and P' at joint x.

f is coefficient of friction,masonary on masonary.

c is cohesion of masonary per square unit.

Design of Dam.

r is specific gravity of masonry.

d is depth of water a joint x.

$H = \frac{d^2}{2r}$ is horizontal thrust of water.

$M = \frac{d^3}{6r}$ is the moment of H about any point in joint x.

W is total weight of masonary on joint x.

w is total weight of masonary on joint 1.

R is the resultant of H and W.

R'is the resultant of the reactions.

a is the angle made by r with the Vertical.

p is limiting pressure per sq. ft. at front face of dam.(112 cu.ft. masonary)

q is limiting pressure per sq. ft. at back face of dam.(140 cu.ft. masonary)

There are four ways in which a dam may fail.

1. By overturning.
2. By crushing.
3. By sliding or shearing.
4. By rupture from tension.

Design of Dam.

To insure ample safety against all these causes of failure, We shall require the profile which is to be determined to comply with the following conditions;-

1. The line of pressure must lie within the center third of the profile, whether the reservoir is full or empty.
2. The maximum pressure in the masonry or on the foundations must never exceed certain fixed limits.
3. The friction between the dam and its foundation, or between any two parts into which the dam may be divided by a horizontal plane must be sufficient to prevent sliding.

In developing a profile similar to the one here developed, a number of designers take account, also, of the upward pressure of any water which may find its way under the heel of the dam and of the pressure which ice, formed on the surface of the reservoir, may exert tending to overturn

the dam. From the very nature of these quantities,they are very indefinite. Also it is believed that with such a foundation as is found in this location,it will be practically impossible for water to find its way beneath the dam so as to exert hydrostatic pressure. It must be remembered that the mere percolation of water underneath the dam,does not mean that there is any hydrostatic pressure present,since if the two bodies,the water behind the dam and the percolated water,are not in direct physical contact there is no resultant upward thrust.

As to the thrust resulting from any formation of ice on the surface,it was not considered advisable to assume an indefinite quantity and increase the area of the cross-section sufficiently to withstandthis added pressure,but rather,the dam was made circular in plan. This would give arch action and not only take care of any ice-pressure but would also give a much greater factor of safety to the dam as a whole.

Design of Dam.

The first of the required conditions given above, eliminate the possibility of tension and insures a factor of safety of two at least against overturning, as will readily be seen by taking moments about the limit of the center third and then about the limit of the joint considered.

The resistance of the dam to sliding has generally been calculated in the following manner;-

If we conceive the wall to be cut by a horizontal plane at a given point, L, there will be two forces which will prevent the upper part from sliding on the lower one,

1. The cohesion of the masonary.
2. Friction.

We must have for equilibrium,

$$H \leq fW + cL.$$

The value of c is considerable for good masonary, but cannot be accurately determined. If we consider cL as a margin of safety and place, $H \leq fW$, ample security against

Design of Dam.

sliding will be insured.

The value of f is given to be between 0.67 and0.75. It may be determined from the equation,

$$f = \frac{H}{W} = \tan a$$

In determining the values of the maximum pressures which occur in the masonary, the distribution of this pressure will determine the formula. This distribution may be one of three cases,trapezoidal,triangular or a condition of pressure and tension both. The following formulae apply respectively, to the above cases;-

$$(1). \quad p = \frac{2W}{1}\left(2 - \frac{3u}{1}\right)$$

$$(2). \quad p = \frac{2W}{1}$$

$$(3). \quad p = \frac{2W}{3u}.$$

In all the calculations for this profile,any stability which the vertical

pressure of the water on the back slope of the dam may add, has been neglected, since this slope is very slight and adds to the factor of safety.

In establishing the equations by which the thickness of the dam is determined the first two conditions are represented in the equations and calculations are made afterwards to determine whether or not the third condition is fulfilled.

In these equations only a lineal foot if the dam is considered and this section is expected to resist, by its own weight, the thrust of the water. Although the dam is a rigid monolith, it is assumed to be divided by horizontal planes ten feet apart to facilitate the calculations.

Since the equations are based on the hydrostatic pressure of the water behind it alone, it would follow that theoretically the top width would be zero. However to insure the necessary strength against blows

Design of Dam.

from floating objects, the top of the dam must have some width. The practice seems to favor an allowance of one-tenth of the height for the top width and this was about 17 feet.

In order that a minimum of material be required, the joints are calculated so as to be on the limit of the given requirements.

Since the top width was not zero as explained above, it is necessary to determine the point at which the width changes. This is found from the equation;-

$$d = a\, r^{1/2}$$

The width of the next joints are calculated from the equation;-

$$x^2-\left(\frac{4w}{h}+1\right)x=\frac{6}{h}(wm+M)+1^2$$

When a joint is reached at which values of nare equal to x/3, this form of equation reduces to the form;-

$$x^2+x\left(\frac{2w}{h}+1\right)=\frac{6M}{h}$$

which is then employed in the calculations.

Up to this point no account has been taken of the pressure in the masonary. From this on, after each application of the equation, the value of the pressure must be calculated to ascertain the point at which the limits of pressure p and q are reached. Since p has been taken less than q, the limit will be reached first in the front face and calculations need be made for p only.

On reaching the limit of pressure, the form of the equation used becomes;-

$$x^2 = \frac{6M}{p}$$

which equation is used until the limit of pressure in the back face of the dam is reached. In finding these values of p and q it must be remembered that thus far the calculations have been made in terms of cubic feet of masonary.

All the succeeding joints are calculated from the equation;-

$$x^2(p + q - h) - 2x(w + \frac{1h}{2}) = 6M$$

Design of Dam.

In determining the joints from the last three equations we simply get the length and not the exact location,due to the fact that both the front and the back faces of the dam have a certain amount of slope. If we determine the batter of the back face, the location is determined. In order to find this batter,y,apply the following equation, after each length has been determined from the respective equation.

$$y = \frac{2w(x-3m) - hl^2}{6w + h(2l + x)}$$

In order to check the values obtained from the above calculations,a vertical axis was chosen at a convenient distance (50 feet in this case),from the back of the top and by the method of moments,the line of pressure was established. This line should agree with the one established by the equations above.

The value of the coefficient of friction was determined from;-

Design of Dam.

$$(A)\quad f = \tan a = \frac{3v}{d}$$

The factor of stability which is denoted by S, was obtained from;-

$$S = \frac{u+v}{v} \quad .$$

############

SPILLWAY.

As will be observed from the data of stream flow, there are periods of the year in which an excessive amount of water must be cared for. To provide for this flood season, it was decided to construct spillways at each end of the dam.

From data obtained by the government for the Pathfinder Dam, it was determined that the maximum flow to be expected at this point would be approximately 20700 second Feet. These figures were arrived at in the following manner. The maximum flow recorded at the Pathfinder dam was 27,600 second feet. The

Spillway.

ratio of the area drained is 0.75. Multiplying the recorded flow by this factor, the value 20,700 was obtained.

From an application of the weir formula;-

$$Q = 3.33\ lh^{3/2}$$

it was found that a spillway 400 feet long and ten feet from crest to top of dam, would allow the discharge of the water, with a depth of 6.25 feet over the crest of the spillway. In case of a flood greater than any yet recorded, there would still be an allowable rise of 3.75 feet before the top of the dam was reached. Hence the maximum discharge of this spillway, allowing the total rise of 10 feet to the top of the dam, would be 42,100 second feet.

In designing these spillways, the fact that water assumes the form of a parabola in flowing over a weir, was used as the basis of calculations. It was desired that the spillway conform to the outlines of the dam proper as nearly as possible, and for this reason

Spillway.

the equation of a parabola which most nearly conformed with the dam profile was chosen. The lower parts of the spillways follow the arc of a circle. The following equations were used;-

Section A-B $y = 4.75\ x^{1/2}$

Section E-F $y = 6.70\ x^{1/2}$

A wall ten feet higher than the spillway and following its outline, will be built between the spillway and the dam, to keep the water on the spillway.

CONTROLLING GATES.

The gates controlling the flow of the water into the penstocks are set at the back of the dam, at the level of the penstocks, 140 feet from the top of the dam. A tower, with an inside diameter of five feet, will be constructed at the back of the dam to afford access to the valves when the dam is full. This tower will consist of a steel sheel 3/4" thick, lined on the outside with concrete sufficiently thick to withstand the pressure.

The gates will be of the valve type and be controlled by motors which are operated from the power house. In case of emergency they can be controlled by handwheels placed at the top of the tower. The motors will be located at the foot of the tower directly in line with the valves.

PENSTOCKS.

The penstocks have a length of 2 miles and in the absence of other data an assumption was made that they follow a straight course along the hydraulic grade line. The first and last 100 feet of the length between down stream wall of the dam and upstream wall of the power house are of steel plate. The remaining 10,360 feet is of wood stave construction. The pressure head,under which the penstocks operate,varies directly with the distance from the dam and therefore the spacing and diameter of the containing steel bands ,as also the thickness of the staves used may be varied over the length of the penstock.

The spacing and size of the bands were determined from a consideration of the pressure head at different equally spaced points along the penstock. The thickness of the wooden stave was left constant throughout.

Penstocks.

If we let, D = inside diameter of penstock, in.

P = pressure of 1foot of water.

h = water head in feet.

Then,

DPh = bursting pressure per lineal inch.

Letting

A = area of steel bands, sq. ins.

p = working strength of steel/ in^2.

Then for safety,

$$DPh = 2Ap$$

The area $A = n \frac{d^2\pi}{4}$

n = number of bands per linealfoot

d = diameter of each band.

Since two unknowns are involved either the diameter or number of bands per foot must be assumed for any section.

The grade is 200 feet in 10,560 feet or one to 52.8. Area of steel bands was figured for every 50 feet of pressure head difference along the whole length. The spacing was assumed.

From the relation given;-

Penstocks.

$$d = \left(\frac{4DPh}{2np\pi}\right)^{1/2}.$$

Calculations based on the above formula give the band diameters as follows, with the number per 100 feet of length of pipe from dam to power house.

(a). 100' feet, 3/8" steel penstock.

(b). 3440 feet stave penstock, 800 bands per 100 feet, 5/8" dia., upset to 3/4".

(c). 1730 feet stave penstock, 800 bands per 100 feet, 11/16" dia., upset to 3/4".

(d). 1730 feet stave penstock, 800 bands per 100 feet, 3/4" dia., upset to 7/8".

(e). 1730 feet stave penstock, 900 bands per 100 feet, 7/8" dia., upset to 1".

(f). 1730 feet stave penstock, 1000 bands per 100 feet, 7/8" dia., upset to 1".

(g). 100 feet steel, 1/2", penstock.

A slope of 1.9 feet per hundred does not call for much anchoring of the penstocks, but they are anchored by embedding in concrete blocks every 200 feet.

To prevent collapse of the penstocks from external air pressure in event of the head

Penstocks.

gates being closed, vertical pipes are fitted into the penstocks near the intake gate. These pipes rise to above the high water level on the dam and are open to the air.

Sudden increase of water pressure at the lower end of the penstocks due to rapid change of the velocity of the water in the penstocks from the closing down of a turbine or other cause, is taken by air cushion formed in an air-tight chamber connected directly to and situated above the penstock. Pressure in these cylinders will be maintained by a motor driven pump.

Provision is made to by-pass all water around the power station if necessary. Manholes are provided wherever needed for the inspection or repair of the penstocks.

In obtaining the dimensions of the penstocks some preliminary assumptions and calculations must be made.

Assuming efficiencies of 97% and 87.5% for alternators and turbines respec-

Penstocks.

tively,and taking 50,000 horsepower as the ultimate generated horsepower,gives the required energy at the gates of the turbine as 59,000.

From the energy relation;-

$$\frac{WV^2}{2g} = 550 \text{ H.P.}$$

Where, W = weight of water per second.

V = velocity per second = $(2gh)^{1/2}$

h = effective pressure head.

Then,

Wh= 550 H.P.

W = 90,000 pounds per second.

Assuming two penstocks in parallel and allowing a velocity of 10 feet per second gives a trial diameter for each penstock,

$$d = \left(\frac{4W}{2\pi jV}\right)^{1/2} = 9.6 \text{ feet.}$$

The loss of head due to friction equals,

$$h' = \frac{V^2}{2g}\left(\frac{41f}{d}\right) = 27.35 \text{ feet.}$$

Where, V = velocity of water in pipe,ft./sec

l = length of pipe in feet.

Penstock.

f = coefficient of friction in pipe.

d = diameter of pipe in feet.

Taking 550 H.P. = W(h - h') and repeatingthe calculations for the new value of W gives a corrected diameter of 10.4 feet for each of the two penstocks. A diameter of 10 feet 6 inches has been used.

DESIGN OF POWER STATION.

The power house is situated on the rightbank of the North Platte river,at a distance of two miles from the dam. Water for driving the turbines is taken from the dam to the power station by two penstocks as described above.

At the power station these penstocks converge and enter the station below the floor level in a single penstock 14 feet 6 inches in-ternal diameter. This steel pipe extends the full distance occupied by the ten generator units,a distance of 205 feet.

The diameter of the pipe changes at each unit so that the mean velocity of the water,for the full length of the pipe,will be constant. Short branch pipes tap the main pipe and convey the water to each unit separately. On each branch pipe is located a gate vavleconnected to the Lombard Automatic regulating mechanism.

After passing through the turbine,

the water falls vertically through the draft tube to the tail-water tunnel from which it flows in a direction perpendicular to the flow in the main pipe,at a velocity of two feet per second. Each turbine unit has a separate tail-water exit tunnel,as described, leading beyond the foundation of the building to the common tail-water canal.

The general layout of the station is as follows; Power is generated by reaction type of turbines direct-connected to the alternators. Electrical energy is taken from the alternator terminals through cables to disconnecting knife switches and form K-2 oil switches in series and to the low-tension buses. From the low-tension buses conductors passes to the low-tension side of the transformers. From the hightension side of these step-up transformers the current is taken through disconnecting knife switches to the form H-3 oil switches and thence through the ducts to the high-tension buses. Two feeder

Design of Power Station.

circuits,connected in parallel,tapped from these buses lead to the terminal station at Laramie,a distance of 100 miles.

TURBINES.

The prposition calls for the ultimate development of 50,000 Horse power in the generating station,and machines are to be installed at first to develop 35,000 horse power as an average maximum load. To do this,seven units of equal capacity are chosen. This would call for units having a K.W. capacity of 3740 K.W.

Allowing for an overload of 50%, would require turbines of,

$$5000 \times 1.5 = 7500 \text{ H.P.}$$

By overload is meant the increase of maximum peak load over average maximum.

The capacity of the turbines, with full gate opening is thus about 1.5 times the normal rating of the generators. This is required in order that the generators may be overloaded at times of peak load or in case

of shut down of any of the units.

The turbines are horizontal, direct-coupled units of the reaction type, built by Morgan Smith & Co., and under normal alternator load take 158 cubic feet of water per second, with a net pressure head of 334 feet. By opening the gate valves to permit each unit to take 200 cubic feet per second, the maximum output is attained and the velocity of the water in the penstocks is increased to 13.34 feet per second as against a normal velocity of 10 feet per second.

Reaction type turbines were selected because of the inherently better regulation and efficiency of the reaction as compared with the impulse type.

Speed regulation of each unit is effected by a Lombard governor belted to the turbine shaft and operating the gate valve on the intake pipe. Each turbine is furnished with a separate pressure oil feed, the oil-pump being belted to the turbine shaft.

Design of Power Station.

GENERATORS.

The generators are 6600 volt,60 cycle,500 R.P.M.,revolving field units,having a rated capacity of 4000 KVA. The normal load is 3740 K.W. per unit,and therefore continuous operation at full normal load may be secured with a power factor of 94% without overheating.

While it would have been better in so far as line regulation is concerned to transmit at 25 cycles over such a long system, the fact that most power systems near this locality are developing at 60 cycles,and the probablity of having to parallel with them, decided the frequency as 60 cycles.

Direct current for excitation is provided at 125 volts,by two 300 K.W.,direct-coupled turbine driven exciters. A third induction motor driven unit is provided. This unit is also of 300 K.W. capacity,and the motor takes power at 6600 volts directly from the low-tension buses. The exciters deliver power to a set of D.C. buses from which

the exciting current for the alternators is taken.

The turbo-exciters are of sufficient capacity to supply excitation for the ten alternators allowing i.5% excitation and the motor-driven unit is installed to take care of part of the excitation and station lighting in case of a shutdown of either of the other turbine-driven exciters.

Station lighting is accomplished by means of inclosed arc lamps taking current from the exciter bus. Distributed 16 candle power lamps supply light for the transformer room,and for the high-tension oilswitch and bus compartment.

LOW-TENSION BUSES.

The generators are connected to the low-tension buses by stranded cables,leading from within the generator base through a concrete duct to the base of the wall upon which the low-tension buses are mounted. Connection is made to low-tension buses through a disconnect knife switch and a K-2 oil switch in series which arrangement makes possible the isolation

of any generator unit.

The cables are rubber-insulated and have an effective area of conductor which is based on an allowance of 1000 amperes per square inch of metallic cross-section, at full load. This gives,

$$A = \frac{I}{1000} = 0.35 \text{ in.}^2$$

The low-tension buses are mounted on insulators on the wall separating the generator room from the transformer room. They are spaced 2 1/2 feet apart. The bus compartments are of marble two inches thick and extends 18 inches perpendicular to the wall. These marble barriers serve to prevent arcing between buses.

The buses are of copper, and have sufficient cross-section to take full-load current from five alternators for a long period without undue rise of temperature. This would be an extreme case and would occur if five alternators for any reason were required to furnish current to the transformers opposite the other alternators.

Design of Power Station.

Since for normal operation the buses would be required to have only sufficient capacity for each unit and since the extreme case referred to above cannot be considered as a very weighty factor, a somewhat high current density is chosen in determining the dimensions of the buses.

Choosing tubular cross-section for the buses and assuming an internal diameter of 1 inch, and a current density of 1400 amperes per square inch, gives an external diameter ($d_2 = 2r_2$) as,

$$\left(\frac{350 \times 5}{1400}\right) = \pi(r_2^2 - r_1^2)$$

From which;-

$$d_2 = 2r_2 = 1.61"$$

A bus having an internal diameter of 1 inch and an external diameter of 1 5/8" would be chosen. Tubular buses are to be used of their greater rigidity for a given metallic cross-section and because of the lower effective resistance as a conductor due to the skin-effect of A.C. current.

Design of Power Station.

The generators are paralleled on the low-tension buses,and the buses are divided by K-2 oil switches into three sections. Only two sections are to be installed for the first seven units,four of which will be feed to one section and three to the other section. The buses are mounted on porcelan insulators placed five feet apart.

TRANSFORMERS.

The transformers are single-phase, oil-insulated,watercooled units having a capacity of 1350 K.W. and a step-up ratio of 100,000 to 6600 volts. The low-tension side is connected delta and the high-tension side is connected star. Cooling water is brought directly from the main penstock. An independant cooling system is arranged for the fifteen transformers belonging to each set of five alternators. From the main penstock a single pipe leads to the transformer room,where it branches.

Design of Power Station

A branch leads along the transformer room wall behind each row of transformers. Taps are taken from these pipes to each unit separately. After passing through the transformer, the water is discharged into the main discharge pipes, located on eadh side of the tracks. The discharge pipes take the water to near the center of the station where they empty into a main which conveys it below floor level to the exciter turbine' water exit.

The supply of cooling water is designed to maintain, if necessary, a constant temperature in the transformers with a heat loss of 10% of their rating. Ordin arily the loss would be about 2% or 3%. For the condition assumed, the heat absorbed would equal the heat generated or,

$$W(t_2-t_1) = 0.10 \times 15 \times 1350k$$

where W = weight of water per second.

(t_2-t_1) = temperature change.

k = factor of K.W. in terms of B.T.U.

Design of Power Station.

Taking, $(t_2-t_1) = 10$

$k = 1.065$

Gives, W = 216 pounds of water per sec.

Allowing a velocity of 10 feet per second in the pipe, the diameter, d, is;-

$$d = \left(\frac{4W}{\pi v j}\right)^{1/2} = 0.665 \text{ ft.}$$

This would be an 8" pipe.

The transformers are on a concealed wheel base and are placed in position on rails. A track runs the full length of the transformer room and is intended for the conveyance of any unit to the repair room or to the station exit. The transformers are of such dimensions that it was thought advisable to place the three units of each set in the form of a triangle. Compactness is secured by this arrangement.

The high-tension leads from the transformers lead directly upwards to the terminals of the oil-switches on the floor above. These switches are G.E. Form F,

Design of Power Station.

type H-3,automatic,remote control,motor-operated ,designed for 100,000 volts and 100 amperes.

Disconnect switches are placed on the line side of the oil-switches as a percaution for safety in case it is necessary to repair the transformers or the switches.

The conductors connecting the oil-switches to the high-tension lines are suspended on insulators and enclosed in a compartment of insulating material. The shortest distance of the conductor to the wall of this compartment is two feet.

The high-tension buses are of aluminum,with tubular cross-section and are suspended from the cross-ties of the roof-trusses by special insulators. The distance between the buses and the grounded roof trusses is four feet. The buses are spaced six feet apart and are at a distance of eight from the nearest point of the oil-switch apparatus. Spacings are in all cases greater than those

given in tables for similar voltages.

The cross-section of the high-tension buses was calculated from the same equation as was used for the low-tension buses. A current density of 800 amperes per square inch was taken as the allowable current density in aluminum, and an internal diameter of one-half inch was assumed. The calculations give;-

Internal diameter	0.5"
External diameter	1.00"

The section was figured to carry the full load output from all ten generator units.

As previously stated the feeders are tapped from the end of the buses. Lightning protective devices are placed between the buses and the feeder circuits.

LIGHTNING ARRESTERS.

Lightning arresters in general fulfill three functions, which are;

1. Guards station from outside disturbance

Design of Power Station.

2. Prevents the spread of disturbances.

3. Renders existing disturbances, harmless.

Electrolytic arresters in combination with reactor coils and horn-gaps are to be installed. The horn-gaps and arrester are connected on the line side of the reactors, with one set of aluminum plates for each line in series with the horn gap, and a third cell connected between these cells and ground. A means for charging the cells is provided.

The arrester will be located in a room on the second floor at the extreme end of the building where the feeder circuits leave the station. It is believed to be the usual practice to locate arresters for very high potential circuits, outside of the building, but since there was sufficient room inside, where they would be free from mechanical interruption from snow, it was thought best to place them inside.

The ground is made by embedding a copper plate in fine charcoal.

Design of Power Station.

BUILDING.

The walls of the building are of granite throughout, since this material is plentiful and a gain in economy is effected by its use. Reinforced concrete is used in all the floors and tunnel walls. The roof covering is slate. Steel trusses spaced twelve feet apart and resting on heavy wall plates, support the roof structure.

Thickness of walls was calculated as follows;-

Height above floor = h = 44 feet.

Weight of cubic foot of masonary = W = 150 pounds.

Crushing strength of granite = 4000 lbs./ square inch.

Working strength of granite = 400 lbs. square inch.

Truss spacing twelve feet.

Roof load per foot length of wall, assumed uniform = L = 3000 lbs.

Weight of 50 ton crane = 80,000

Design of Power Station.

Maximum wall reaction for crane and roof load = R = 124000 lbs.

Thickness of wall in feet. = t

For safety from lateral buckling take t less than h ÷ 15,

Then, $\frac{R + L}{tl} + Wh = 144p$

Since l = one.

$$t = \frac{R + L}{(144p - Wh)} = 2.54 \text{ feet.}$$

This would be safe for a solid wall in crushing. To fill the condition that t is less than h ÷ 15, and to allow for increased unit stresses due to window spaces, this thickness is increased to 3.5 feet for all walls.

The oil-switch floor was designed to withstand the weight of the oil-switches with a working stress of 15,000 pounds per square inch in the steel I beams. The oil-switches weigh approximately 30,000 pounds and this was considered as being supported at the center of four I beams of equal di-

Design of Power Station.

mension.

Taking, $p = 15{,}000$ # per sq. in.

$l = (34 \times 12)$ inches.

$P = W/4$.

and equating internal to external moments gives;

$$\frac{pI}{e} = M = \frac{Wl}{16}$$

from which,

$$Z = 51$$

This corresponds to the section modulus of a 8 inch I-beam.

The oil-switch floor is the standard Roebling construction, concrete reinforced with expanded metal and is capable of sustaining a floor load of 1000 pounds per square foot.

The repair shop, office and lavatory are located at the down-stream end of the station on the first floor. The main entrance to the station is at this end also. A railway track is laid through the station for the purpose of bringing machinery within the station.

TRANSMISSION LINE.

The principle factors which enter into the design of a transmission line are reliability of service and economy. The relative values given to these factors depend entirely on local conditions. In this design reliability of service was considered of most importance, for two reasons. First, fully ninety per cent of the power is to be used in the mines where it is absolutely necessary that power be available all the time. Second, there are no other generating station in the vicinity from which power can be obtained, therefore, it is necessary that the transmission line be in operating condition all the time.

There will be one tower line from the generating station to the terminal station. This line will carry two circuits which under normal conditions will operate in parallel, each circuit carring one-half the power. In case of a break-down on one or more of the

wires it is so arranged at the generating station that any three of the six wires can be transposed to form one circuit over which the total power may be transmitted. Each circuit was designed to operate most economically when carrying one-half of the total power. Therefore, the line loss will be quite large when one circuit has to carry the total power during the time of a break-down on one or more of the wires. Operating reports of other high-tension lines under similar conditions show that the time during which one circuit may have to carry the total power is so small compared with the total time that this factor may be neglected.

The next assumption which it was necessary to make was the value of the load factor. As has been stated, approximately 90% of the load will be at the mines. Since this load is fairly constant throughout a twenty-four hour day, it was thought safe to take the load factor at 70%.

There are at the present only two

materials,copper and aluminum,in general use for conductors.

For the same relative conductance the relation of the various characteristics are given in the following table.

	Copper(hard drawn)	Alum.
size	1	2
weights	1	0.48
cost(copper at 15¢,aluminum at 31¢).	1	0.992
tensile strength	1	0.752

The above comparison shows a very slight saving in the first cost by using aluminum and a decided saving in transportation cost. The larger diameters of conductors necessary when aluminum is used are also points in its favor. This is due to the decrease in corona loss with an increase in the size of conductor. Aluminum has a decided disadvantage in that its tensile strength is low. However,it has been proven in practice that the tensile strength is sufficient for high tension transmission work. The above com-

parison favors the aluminum and since it has proven satisfactory wherever used it was decided to use it for this transmission line.

In calculating the transmission line the method given by M.W. Franklin in the General Electric Reveiw for 1909-10, was used. The assumptions made are those which agree more nearly with present practice in similar cases. The following is the notation, values of the different factors, and the equations used in calculating the size of conductor.

P = power at generating end, max. = 25,000

P_1 = power at generating end 70% load factor = 17,500 K.W.

P_2 = power at generating end per circuit = 8750

c = estimated cost of power/ K.W. year = $16

E_R = voltage at receiving end 95,000

Cos ϕ = Power factor at receiving end = 85%

c_1 = cost of conductor per pound(31¢).

p = interest rate (5%).

K_1 = resistance per mil foot mile. = 88,500

Transmission Line.

K_2 = weight of conductor per mil mile

= 0.00486 pounds.

L = length of line = 100 miles.

S = section of conductors, circular mils.

x = line loss, in terms of impressed quantities.

$$S = \frac{1000(1-x)^2 P_2 K_1 L}{E_R^2 \cos^2\phi \; x}$$

$$x = \left(\frac{3K}{4cE_R^2 - 3K}\right) 1/2$$

$$K = \frac{4000 \, pc_1 K_1 K_2 L^2}{\cos^2\phi}$$

In calculating the voltage at the generating end, and the regulation of the line the capacity and inductance were considered as connected, one sixth at each end and two-thirds at the center. The values for the capacity and inductance of the line were calculated and checked by the tables given by M.W. Franklin. The formulae are;

$$C = \frac{0.0388}{2 \log \frac{d}{R}}$$

Transmission Lines.

$$L = (80.5 - 740 \log(\frac{d}{R})\ 10^{-6}$$ Henries/mile per wire.

$$I = \frac{4\ \pi\ f\ C\ E}{\sqrt{3}\ 10^{6}}$$ amperes per wire.

d is the distance between wires in inches.

R is the radius of the wire in inches.

I is charging current in amperes.

The results of the calculations are;

size of conductor	0000 B & S
line loss	6.38 %
cpacity of line	.73 m.f.
inductance of line	207.5 m.h.
Charging current	30.3 amp.
line regulation	7.88%
Power factor,generating end,	1.00

As has been stated,two circuits are to be used supported on a single tower line. The standard tower will be of the windmill type and of the design shown in the plate. In determining the height of the tower,it was necessary to calculate the sag of the wire. The following notation,value of the different factors,and equations were used;-

Transmission Line.

L is the length of the line span(assumed) 600 feet.

d is the sag in feet.

T is tension(at the elastic limit)13,000 pounds per square inch.

W_1 is weight of wire per foot of length. 0.195 pounds.

W_2 is weight of ice/foot. .636.

W_3 is weight due to wind pressure 8 pounds per square inch projected area, 1.015#

W is resultant, of W_1, W_2, W_3 taking W_3 acting at an angle of 45° from vertical. 1.819 pounds/foot of length.

$$d = \frac{L^2 W}{8 T}$$

Solving the above equation gives a sag of 21.5 feet at the center of the span. Allowing a minmum distance of the conductor above ground of 25 feet, the height of the tower to the lowest cross-arm was found to be 50 feet. Where it will be necessary to use longer spans, on account of the topography

of the country,the tower will be made higher by adding sections to the lower end,beginning at the lowest horizontal bar. The entrance towers at the generating station and terminal station are to be of slightly different design as is shown in the plate.

The suspension type of insulator will be used. Each insulator is composed of six discs,ten inches in diameter,with three petticoats on the under surface. Each disc will stand a wet test of 56,000 volts and a dry test of 90,000 volts. The insulator of six discs will stand a wet test of 265,000 volts and a dry test of 340,000 volts.

As is shown in the plate,the distance from the tower to the point of support of the insulator is eight feet. This makes the minimum distance,of the tower to the conductor, five and one-half feet,when the insulator is swinging at an angle of 45° from the vertical. The vertical distance between conductors is 10 feet,but under normal conditions the upper and lower conductors on one side of the tower

form a circuit with the middle conductor on the other side of the tower, so that the spacing between the conductors of the same circuit are 20.5feet, 22 feet and 24 feet. The ground cable is 5/8th. inch in diameter made of seven strand steel wire and is supported at the very top of the tower, 10 feet above the highest cross-arm.

SUMMARY.

Length of line	100 miles.
Maximum power transmitted	25,000 K.W.
Line voltage	100,000 V.
Line loss	6.38%
Capacity of line	0/73 m.f.
Inductance of line	207.5 m.h.
Charging current	30.3 amp.

TERMINAL STATION.

The terminal station is to be located at Laramie, as near the center of the power market as possible. The building will be a two-story structure built of granite. It will be 90 feet long 66 feet wide and 51 feet high. The floors are to be of reinforced concrete and the roof is to be a 3 1/2 inch reinforced concrete slab, supported on 10 inch I-beams spaced 10 feet centers.

The high-tension line will enter the station through the roof, and all the high-tension wiring and apparatus will be on the roof and second floors. The lightning arresters are the same as those used in the generating station, except the horn-gap and disconnect switch. There was not sufficient over-head room in the station to accommodate the horn-gaps, therefore, they were put on the roof just above the lightning arrester tanks. The disconnect switch is of the horizontal type, and is located on the roof also.

Terminal Station.

Both the horn-gaps and the disconnect switches are operated from the second floor.

On account of the high-tension wires entering through the roof and the high-tension bus-bars being suspended from the roof, K-10 oil-switches were used instead of H-3. Since the terminals of the K-10 oil-switches are on the top, less wiring is required. also, the space occupied by the K-10 switch is not so great.

The transformers and all low-tension apparatus are located on the first floor. The transformers will be of the Westinghouse make of 2,670 K.W. capacity each, and will step the voltage down from 100,000 to 13,200. Cooling water for the transformers will be obtained from a well located, under the transformer repair room. The water will be pumped from the well by a centrifugal pump, of 242 gals per minute capacity direct connected to a 12 H.P. 440 volt squirrel cage induction motor. The transformers are mounted on wheels so they can be taken out for repairs.

Terminal Station.

The repair room will be equipped with a 30 ton crane so that the transformer coils can ,at any time be lifted from the casing for inspection and repairs. A room will be built under the repair room to hold two tanks for removing and filtering the transformer oil. A motor driven pump will be provided for removing and returning the oil to the transformers.

The transformers are connected star on the high-tension side and delta on the low side. The leads from the low-tension side of the transformers enter ducts and go to the K-2 oil-switches located on the center wall. Through leads run from these switches, in floor ducts to the low-tension buses on the outside wall.

Eight out-going lines are to be used,two going to Laramie and six to the mines. The wires will leave the station through ten inch tiles placed in the wall in the same manner as the outlets in the generating station. Cedar pole-line con-

struction will be used with pin type of insulators.

The terminal station switch-board will consist of three transformer panels, duplicates of those in the main generating station, one station panel and one panel for the oil-switch control of incoming and outgoing lines. There will be no instruments on the outgoing lines as it is proposed to measure the power at the customers substation.

A 20 K.W. motor-generator set will supply direct current for the station. If there should be a considerable dem and for direct current there is sufficient room in the station for a synchronous converter. Also if future growth should warrant the building of a steam plant to operate in parallel, the building could be extended to accommodate the steam plant.

GENERAL ESTIMATE OF COST.

The figures given below for the cost of the plant are intended to be approximate only. They were taken from such data as was available on other installations and do not represent bid prices for this development.

Based on figures taken from the Electrical World of 1910, the cost of the generators was taken at $ 11.00 per Horse power generated. Taking the present installation of 35,000 H.P.

11 x 35,000 = $ 385,000

The cost of transformers was based on figures from "Data", at $ 6.50 per K.W. Each transformer will be rated at 1350 K.W. and there will be 21 installed.

21 x 1350 x 6.50 = $ 184,000

The switch-board and station wiring was based on proportional costs given in the "Standard Handbook" by Cary Hutchinson. This data gives the switchboards and wiring at 9/40 of the generator and transformers.

9/40 x 569,000 = $128,000

General Estimate of Cost.

The cost of the water wheels and governors was taken from the same source as the switchboard and was given as 36.65/40 of the cost of generators and transformers.

36.65/40 x 569,000 = $ 521,000

The cost of the building was taken at $ 5.00 based on data given in the "Electrical World" and in "Data".

26,100 x 5 = $ 130,500

"Data" gives the cost of installing a transmission line similar to the one considered for this development in all essential details. These figures are taken from actual results and are given at $4800 per mile. The line will be 100 miles long.

100 x 4800 = $ 480,000

Also "Data" gives the cost of installing a number of substations similar to the one considered here. As an average of these figures the cost of building was taken at $ 3.80 /K.W. and the equipment of transformers etc. at $ 8.50 per K.W. The station will be 25,000 K.W. capacity.

General Estimate of Cost.

25,000 x 12.30 = $ 307,000

The Dam for this project will contain approximately 126,000 cubic yards of masonary. The stone can be quarried from the neighborhood and will be laid in a cement motor. The average cost of the completed dam was taken at $ 5.25 per cubic yard based on results of other similar dams. The one corresponding most nearly with this dam was a granite dam at Cheyenne Wyoming. In this dam a 1:4 mortor was used and constituted 35.2% of the dam, requiring 0.61 bbls. of cement per cubic yard of masonary. The stone was quarried at a cost of $ 1.96 / cu. yd. and the cement cost $ 3.58 per barrel delivered.

126,000 x 5.25 = $661,000

The cost of the penstock was taken at $ 30.00 per foot. There will be two penstocks each two miles long.

2 x 2 x 5280 x 30 = $ 633,000

An allowance of 10% was made for engineering and contingencies which brought the

<u>total cost to</u> ---------- $ 3,772,400

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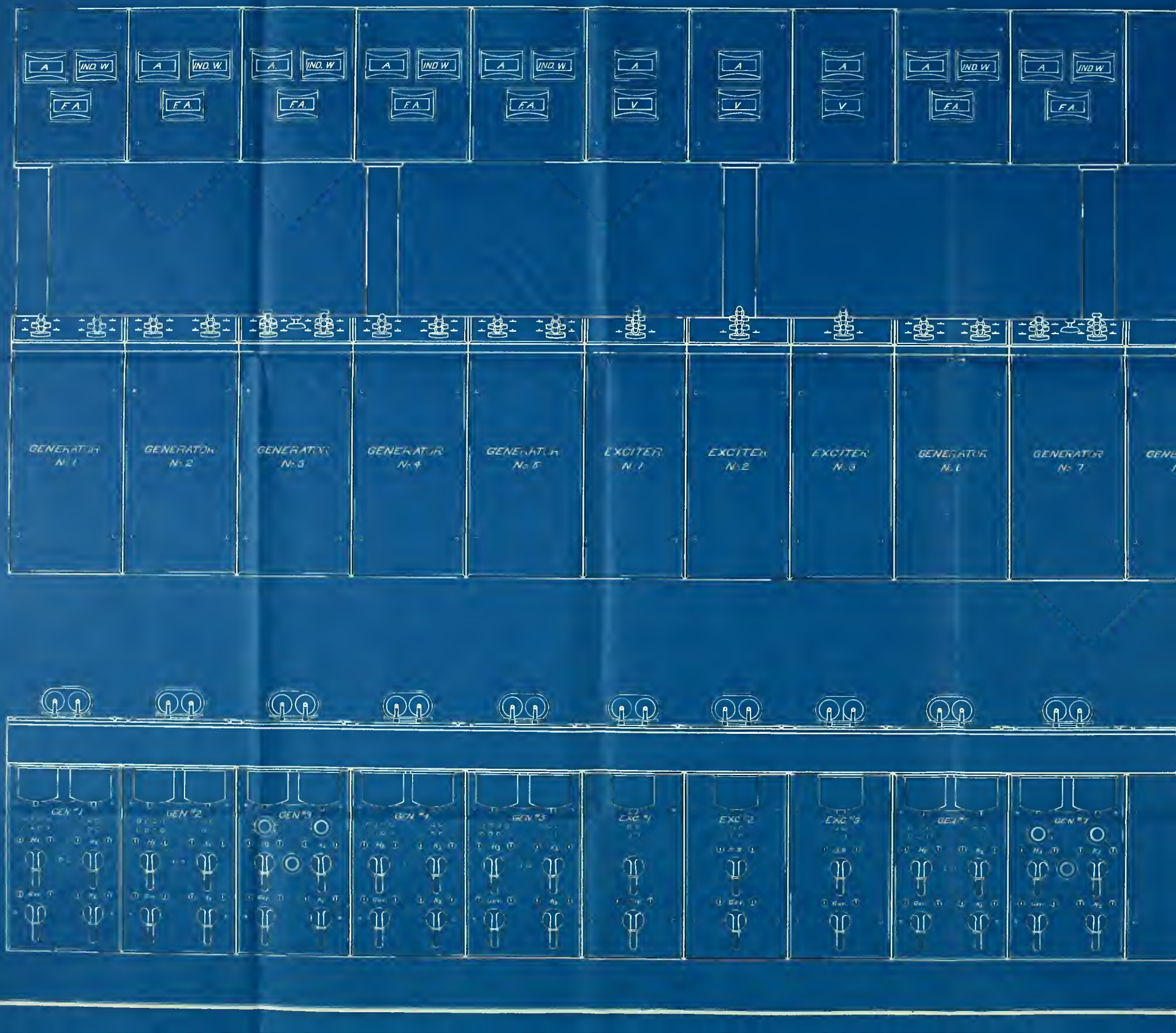
A
IND. W
F.A.
V
GENERATOR No. 1
GENERATOR No. 2
GENERATOR No. 3
GENERATOR No. 4
GENERATOR No. 5
EXCITER No. 1
EXCITER No. 2
EXCITER No. 3
GENERATOR No. 6
GENERATOR No. 7
GEN No. 1
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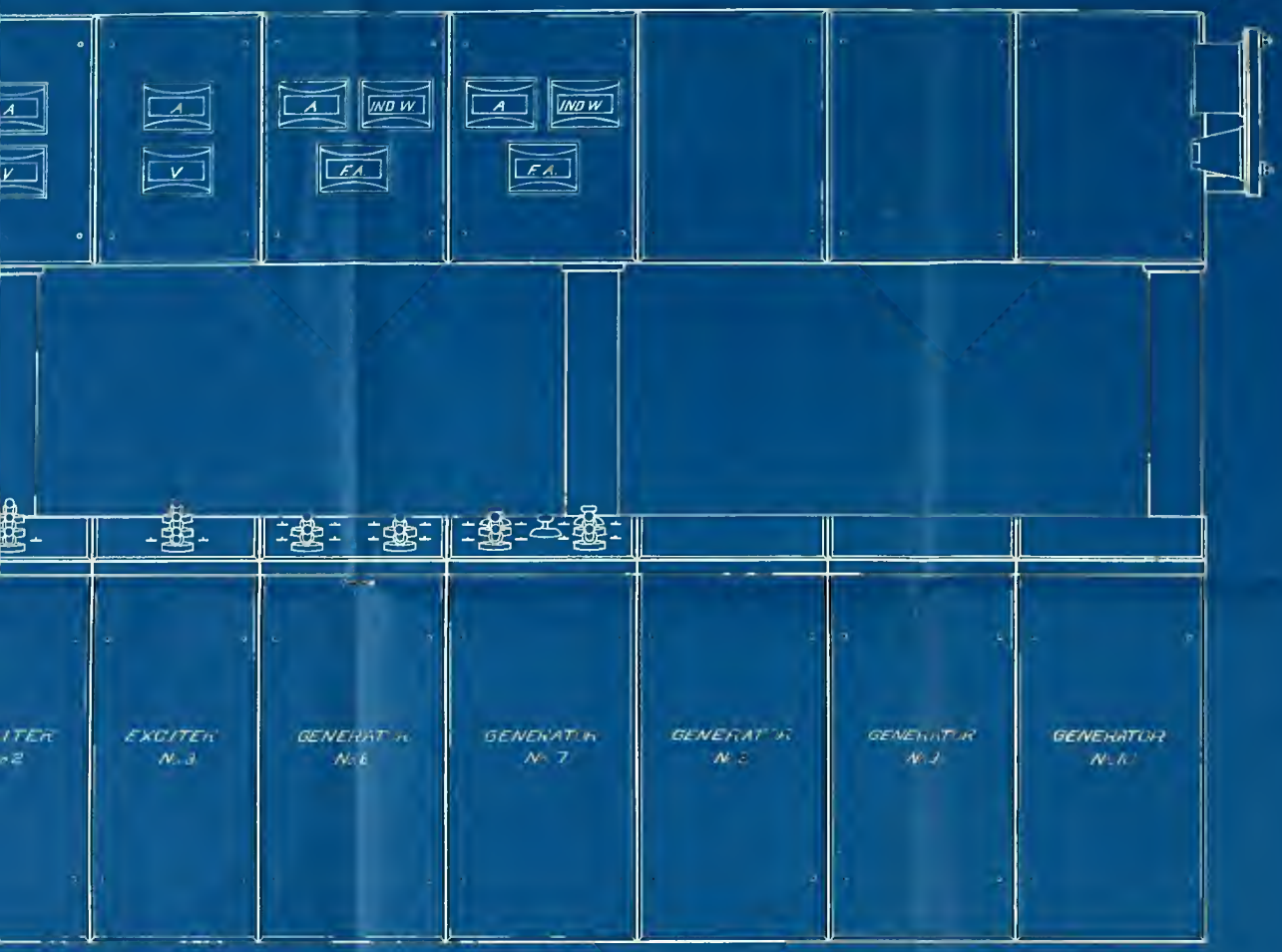
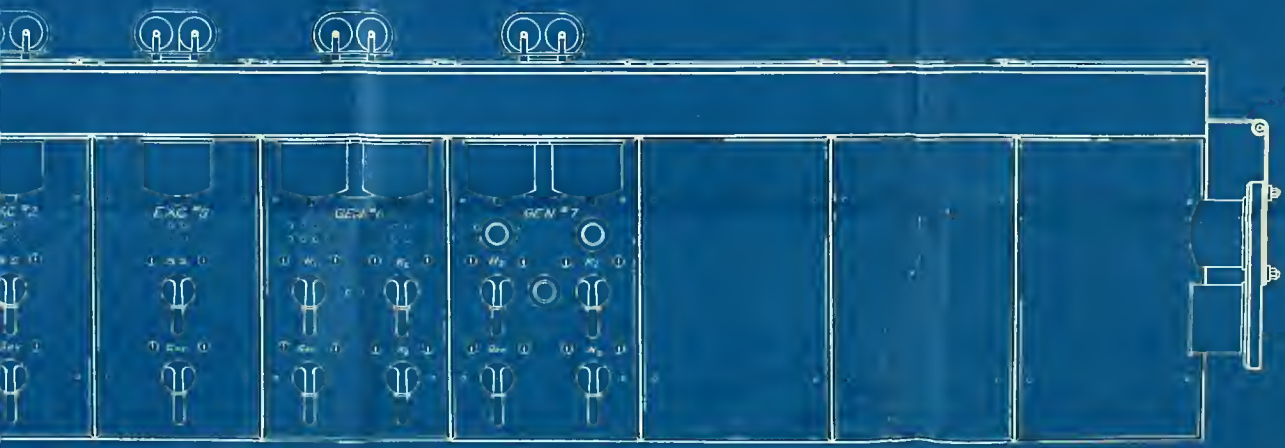
GEN No. 4
GEN No. 5
EXC No. 1
EXC No. 2
EXC No. 3
GEN No. 6
GEN No. 7





PROPOSED HYDRO-ELECTRIC DEVELOPMENT ON NORTH PLATTE RIVER.

DRAWN BY J.A. CHECKED BY A.L.

TRACED BY J.A.

ARMOUR INSTITUTE OF TECHNOLOGY

CHICAGO ILL. MAY 24 1912

CONTROL SWITCH BOARD.

SCALE 1/2 = 1 FT

TRUSS DIAGRAM.
SCALE 1"=4'.

DEAD LOAD
SCALE 1"=5 TONS

WIND LOAD.
SCALE 1"=25 TONS

PROPOSED
HYDRO-ELECTRIC DEVELOPMENT.
ON
NORTH PLATTE RIVER, WYO.

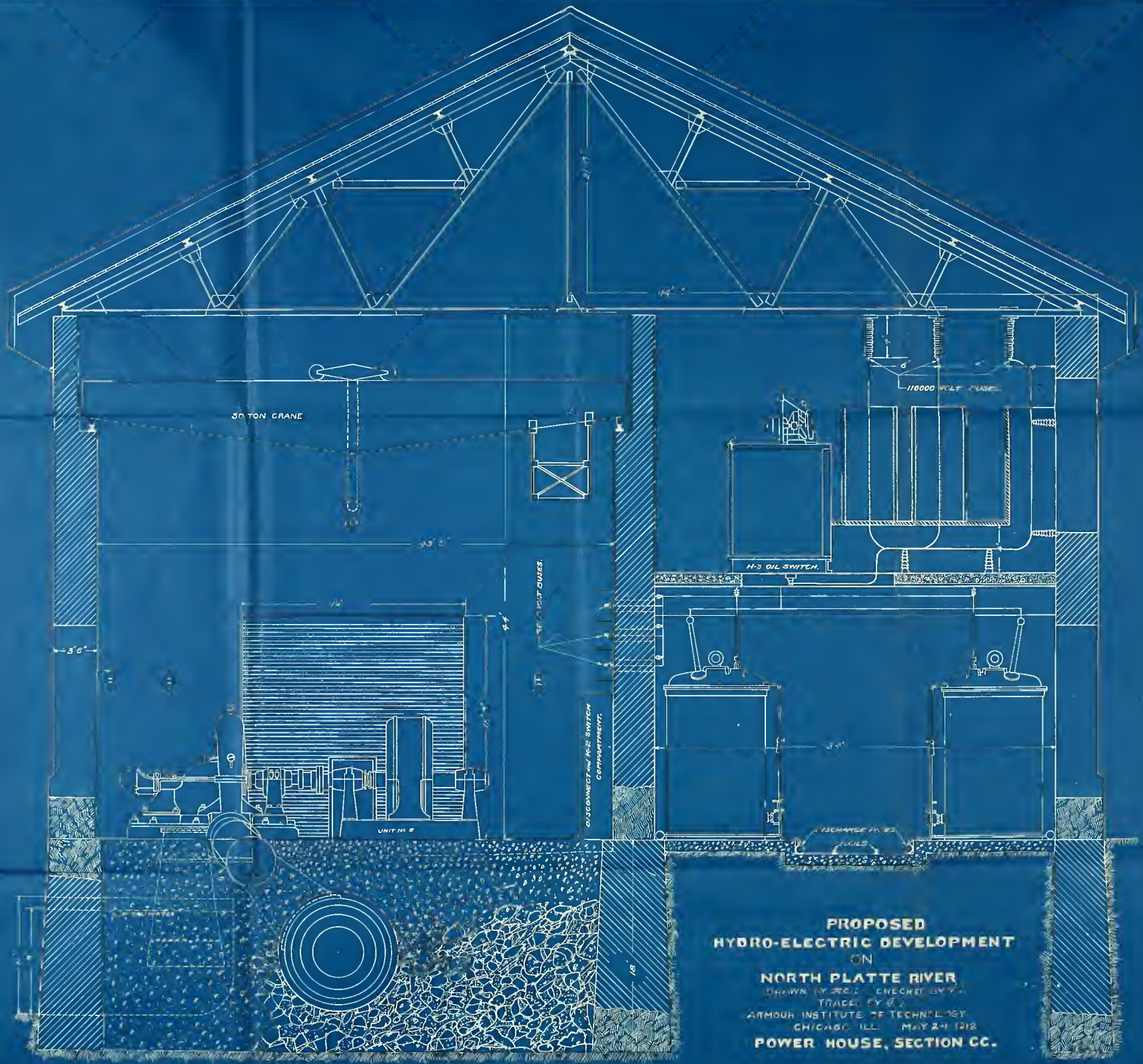
ARMOUR INSTITUTE OF TECHNOLOGY

DRAWN BY [illegible] CHECKED BY [illegible]

TRACED BY [illegible]

MAY 25th 1916 SCALE - GIVEN

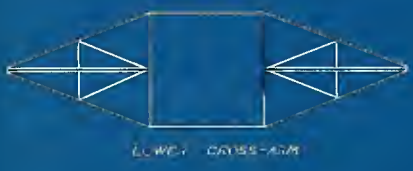
STRESS DIAGRAM
OF
ROOF TRUSS.



PROPOSED
HYDRO-ELECTRIC DEVELOPMENT
ON
NORTH PLATTE RIVER
DRAWN BY [illegible] CHECKED BY [illegible]
TRACED BY [illegible]
ARMOUR INSTITUTE OF TECHNOLOGY
CHICAGO ILL. MAY 24 1912
POWER HOUSE, SECTION CC.

UPPER CROSS-ARM

MIDDLE CROSS-ARM



LOWER CROSS-ARM

PORCELAIN INSULATOR
Size 2"×7"

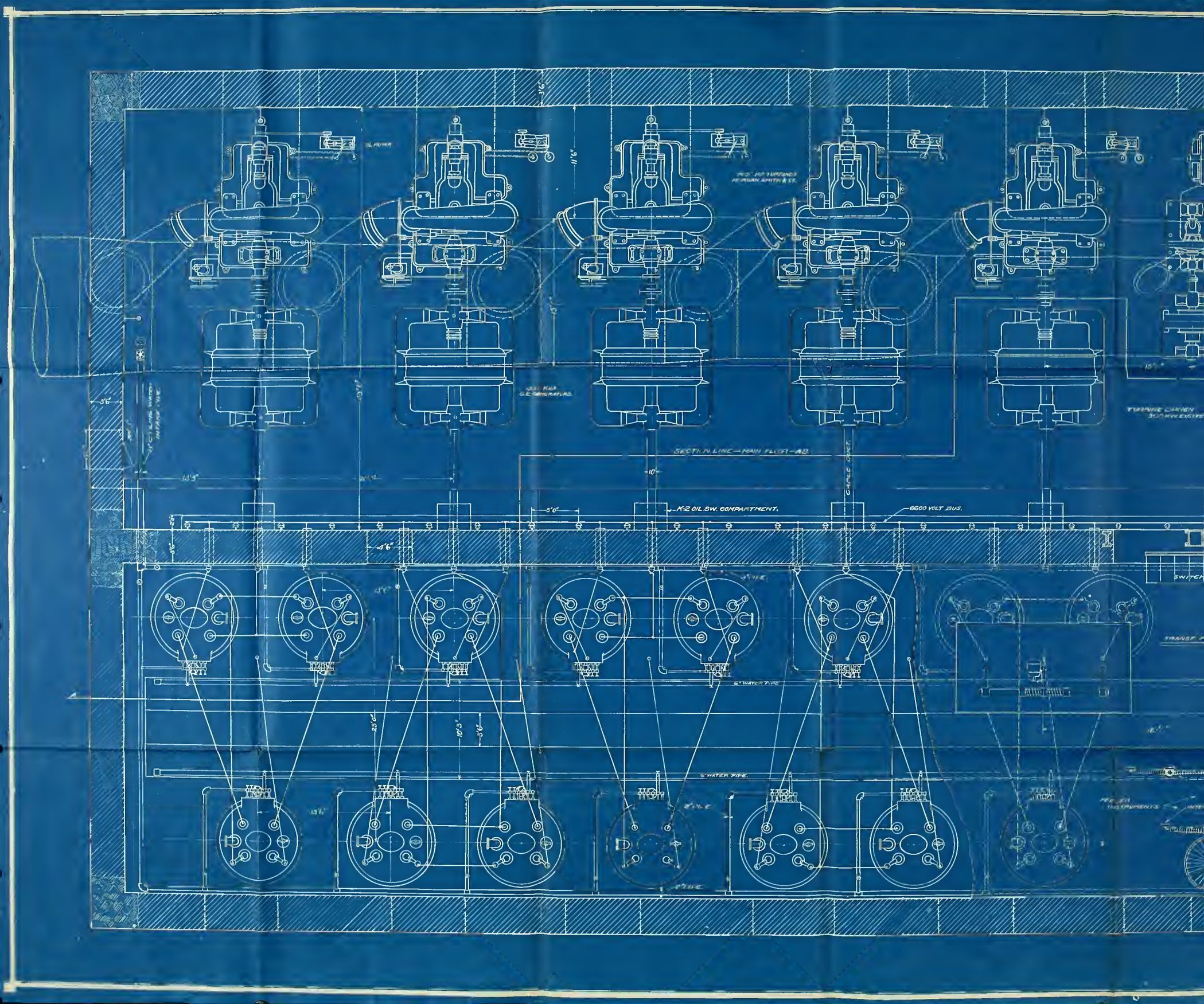
PROPOSED
HYDRO-ELECTRIC DEVELOPMENT
ON
NORTH PLATTE RIVER, WYO.

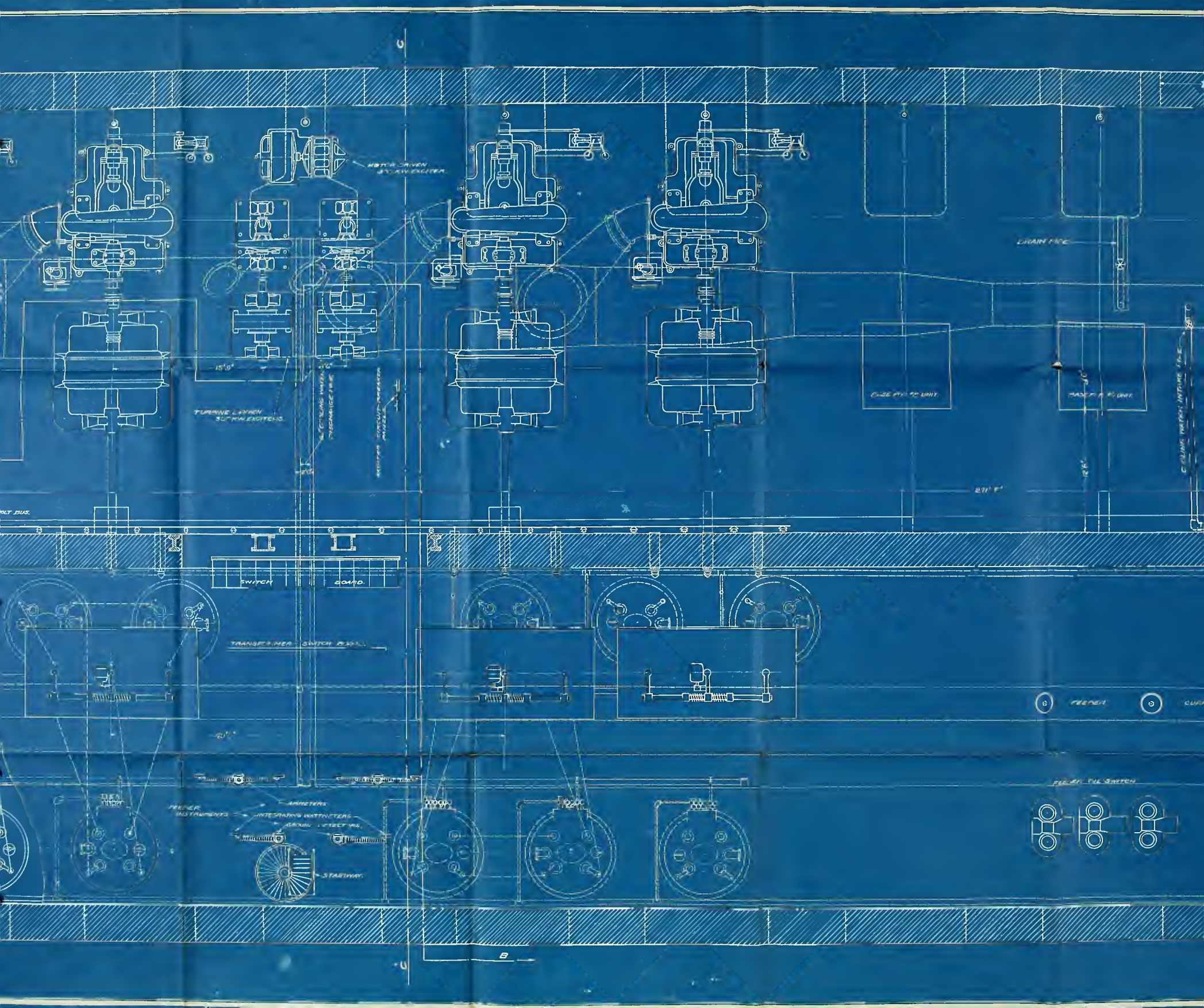
DRAWN BY [illegible] CHECKED BY [illegible]

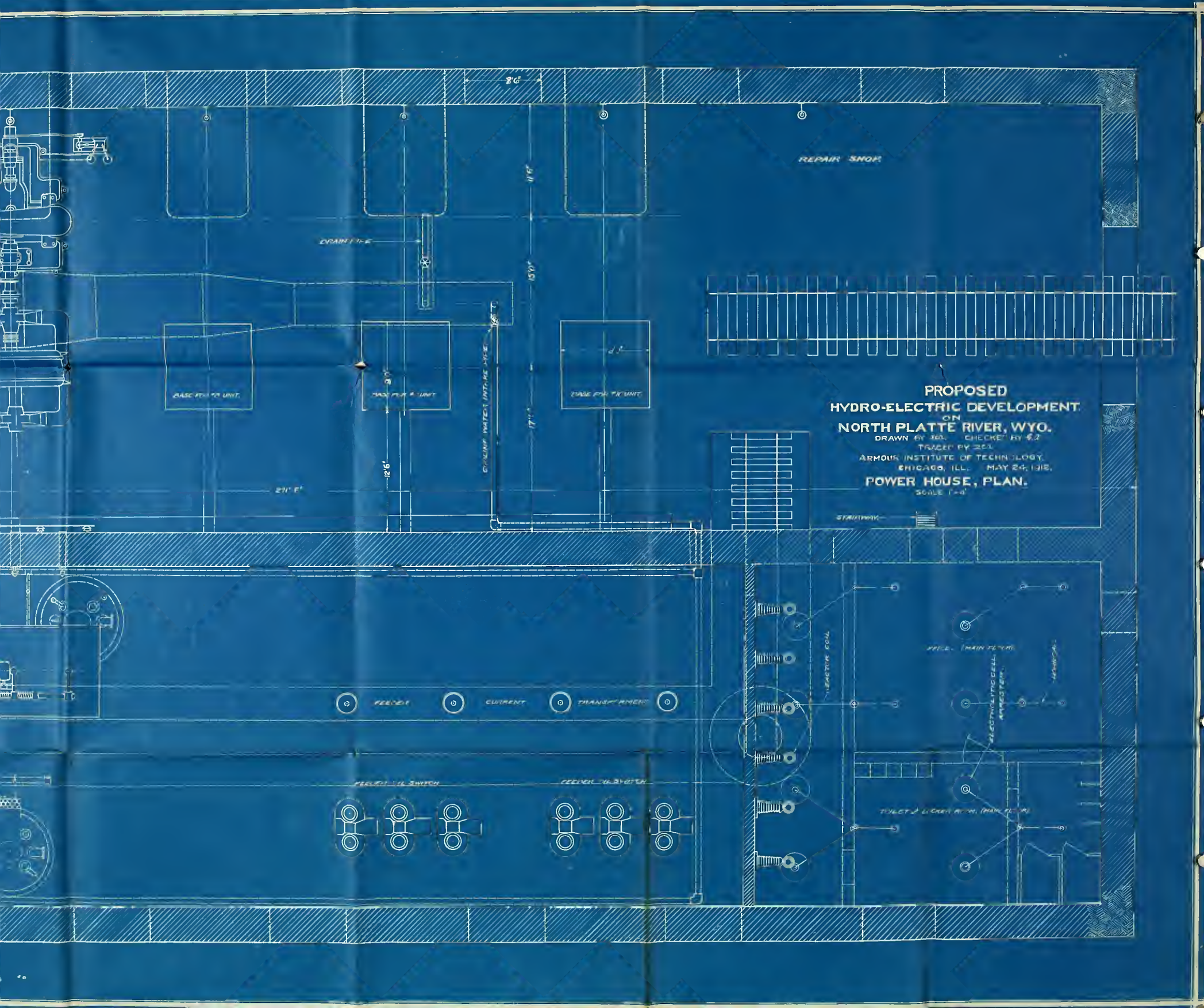
TRACED BY [illegible]

ARMOUR INSTITUTE OF TECHNOLOGY,
CHICAGO, ILL. MAY 2-4, 1912. SCALES 1" = 1'-0" & 2"=1'

STANDARD TOWER & INSULATOR.


SECTION LINE — MAIN FLOOR — AB.
K-2 OIL SW. COMPARTMENT.
6600 VOLT BUS.
CABLE CHUTE.
6" WATER PIPE.
6" WATER PIPE.
SWITCH

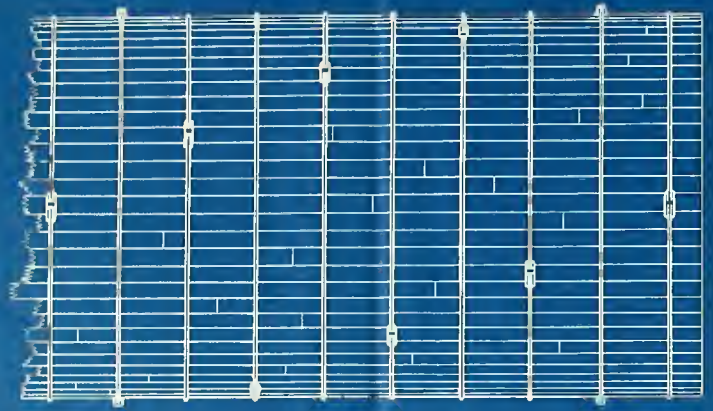

MOTOR DRIVEN D.C. EXCITER
TURBINE DRIVEN D.C. EXCITER
DRAIN PIPE
SWITCH
BOARD
TRANSFORMER SWITCH PANEL
FEEDER
FEEDER INSTRUMENTS
AMMETERS
INTEGRATING WATTMETERS
AUTOMATIC CIRCUIT BREAKERS
STARTING
FEEDER OIL SWITCH
B


REPAIR SHOP
PROPOSED
HYDRO-ELECTRIC DEVELOPMENT
ON
NORTH PLATTE RIVER, WYO.
DRAWN BY
CHECKED BY
TRACED BY
ARMOUR INSTITUTE OF TECHNOLOGY.
CHICAGO, ILL. MAY 24, 1912.
POWER HOUSE, PLAN.
SCALE
STAIRWAY
FEEDER
CURRENT
TRANSFORMER
FEEDER VOLTMETER
EXCITER COIL
ELECTROLYTIC CELL ARRESTER
TOILET & LOCKER ROOM (MAIN FLOOR)

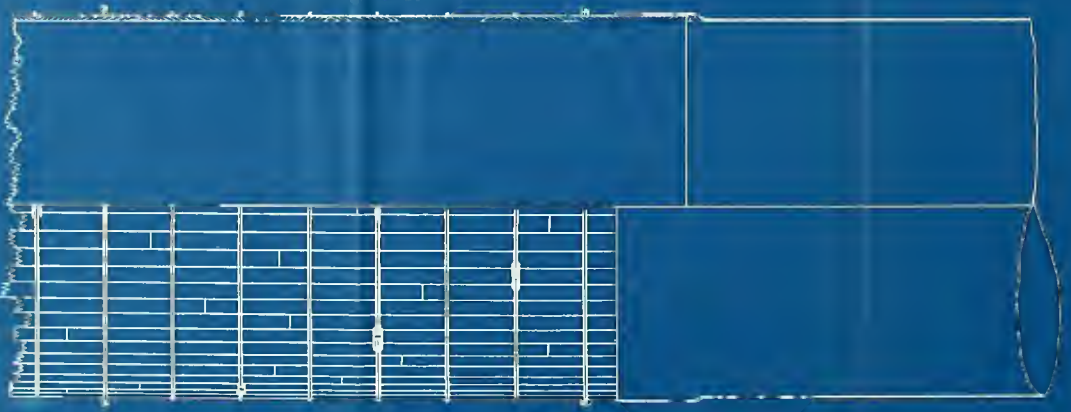
PROPOSED
HYDRO-ELECTRIC DEVELOPMENT
ON
NORTH PLATTE RIVER, WYO.

DRAWN BY T.J.S. CHECKED BY S.C.J.
TRACED BY W.L.A.
ARMOUR INSTITUTE OF TECHNOLOGY
CHICAGO ILL. MAY 2ND 1912 SCALE 1:400

CONTOUR MAP OF DAM SITE



BAND CLAMP.



PROPOSED
HYDRO-ELECTRIC DEVELOPMENT
ON
NORTH PLATTE RIVER, WYO.

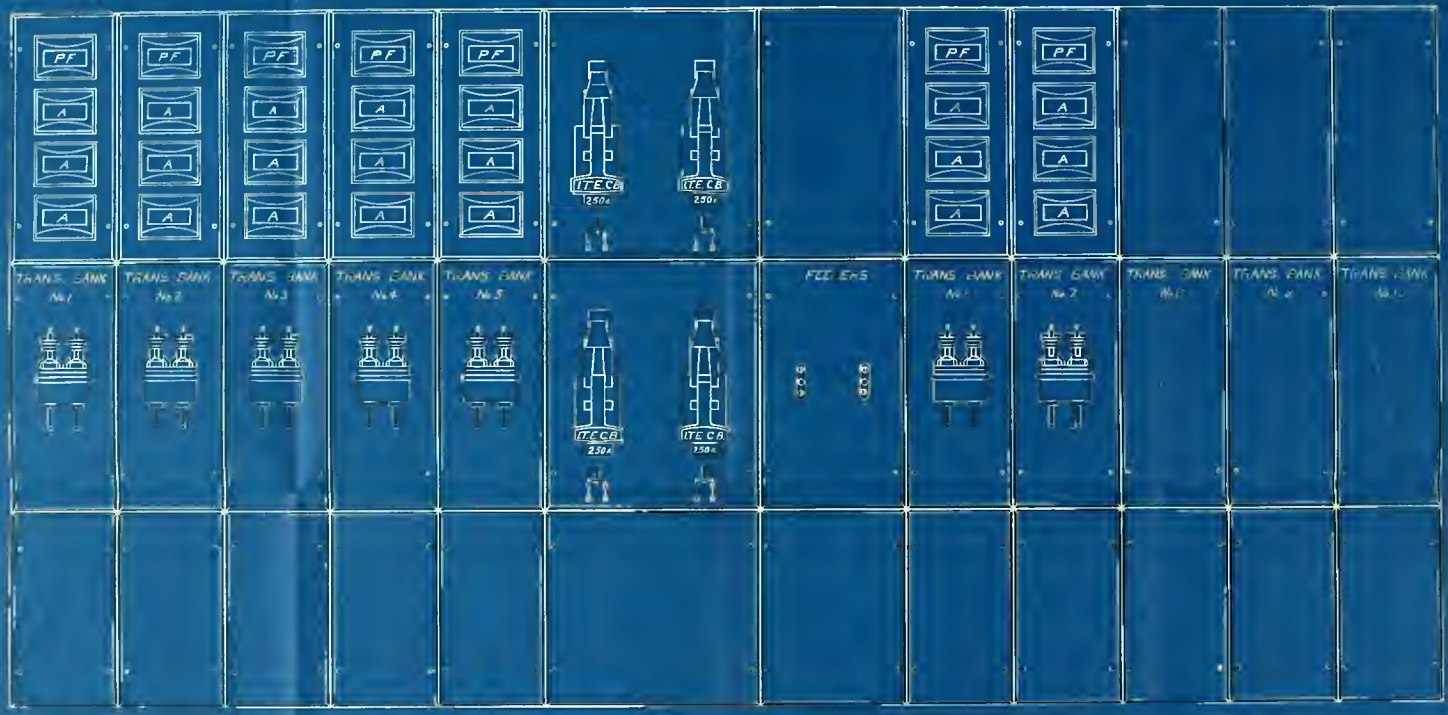
DRAWN BY [illegible] CHECKED BY [illegible]

TRACED BY [illegible]

ARMOUR INSTITUTE OF TECHNOLOGY

CHICAGO ILL. MAY 24 1912 SCALE 1" = 1'

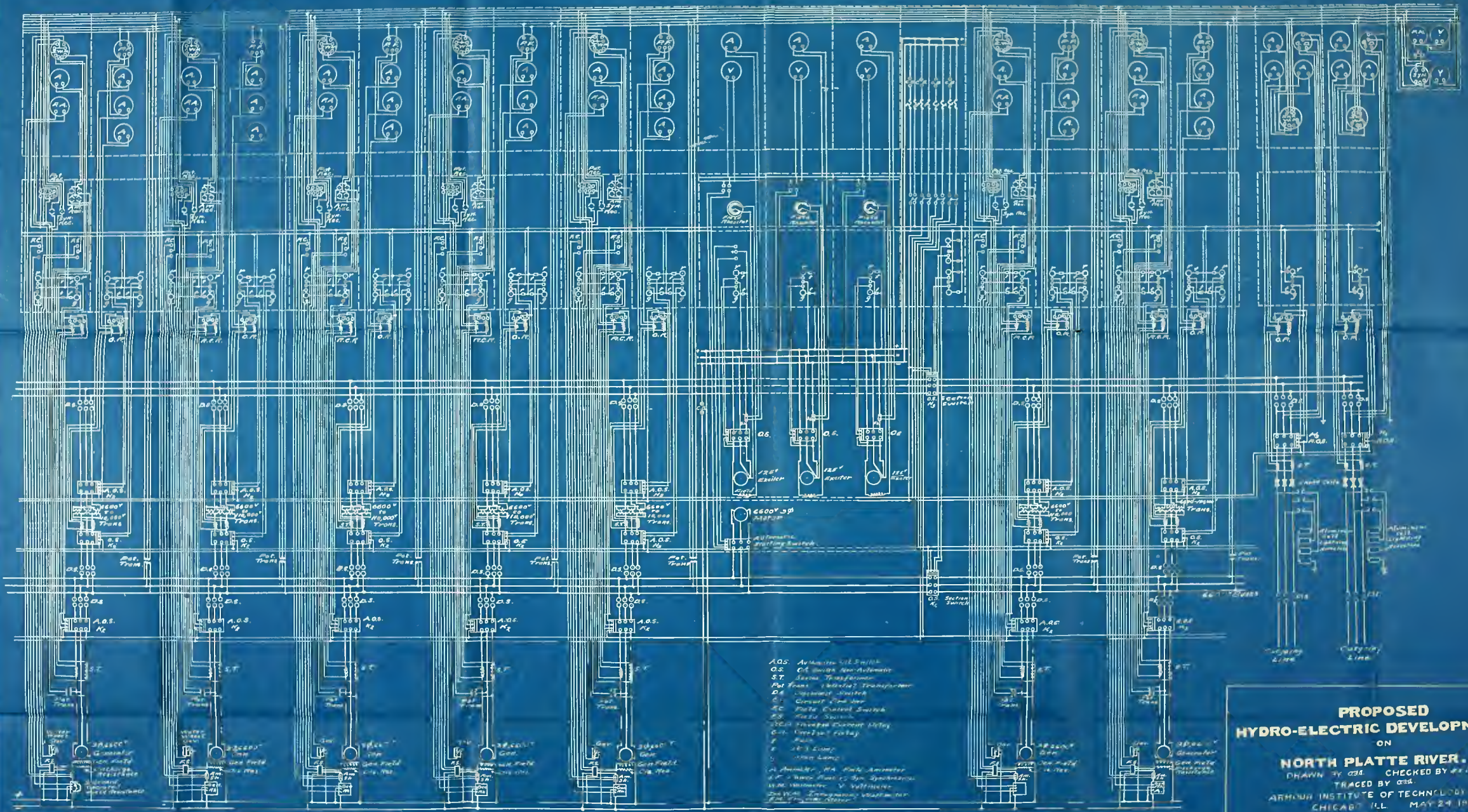
SECTION OF PIPE LINE.



PROPOSED
HYDRO-ELECTRIC DEVELOPMENT
ON
NORTH PLATTE RIVER WYO.

DRAWN BY [illegible] CHECKED BY [illegible]
TRACED BY [illegible]
ARMOUR INSTITUTE OF TECHNOLOGY
CHICAGO ILL. MAY 24 1912 SCALE 1/2"=1'

TRANSFORMER SWITCH BOARD.



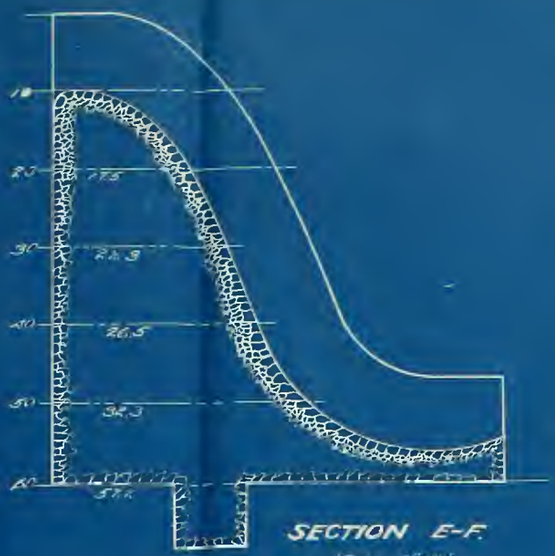
PROPOSED
HYDRO-ELECTRIC DEVELOPMENT
ON
NORTH PLATTE RIVER.

DRAWN BY ... CHECKED BY ...

TRACED BY ...

ARMOUR INSTITUTE OF TECHNOLOGY
CHICAGO ILL. MAY 24 1912

WIRING DIAGRAM.

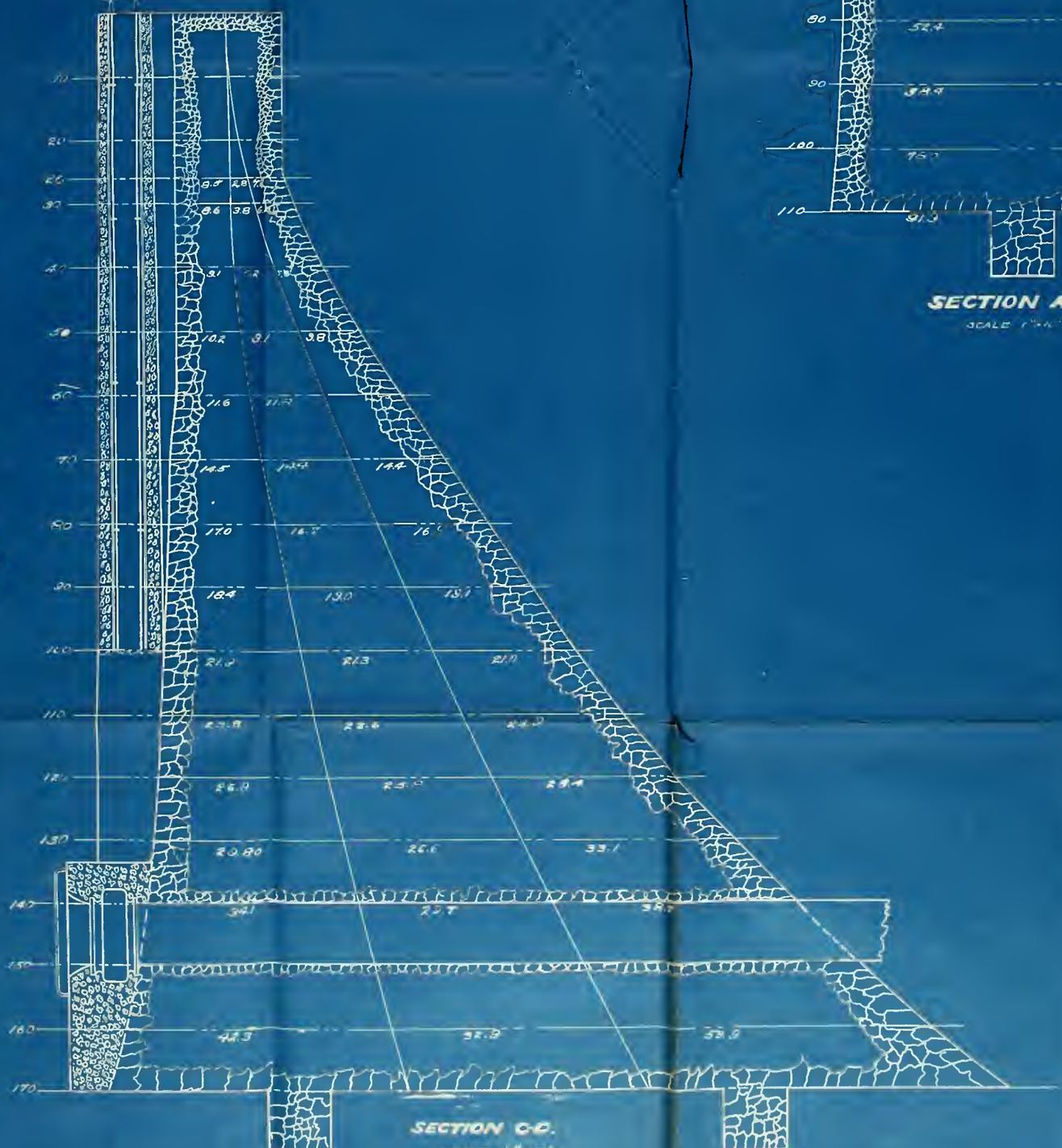


SECTION E-F.

SCALE 1"=10'

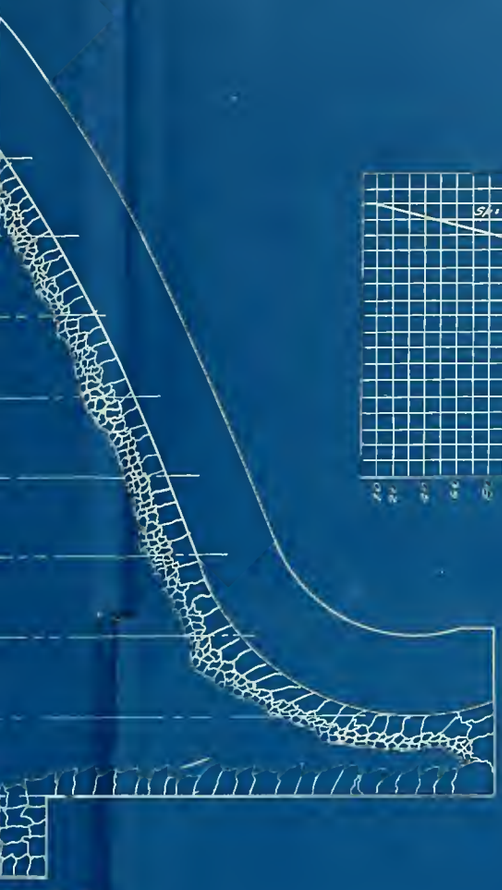
SECTION A-B.

SCALE 1"=10'

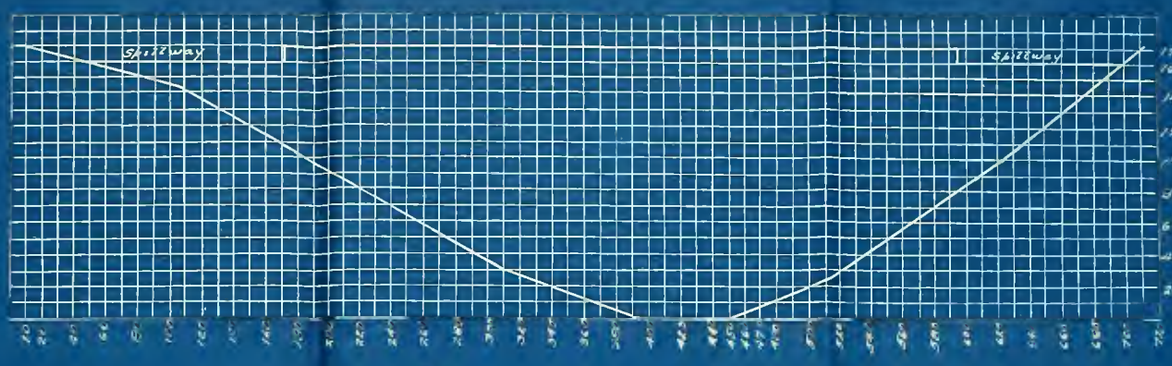


SECTION C-D.

SCALE 1"=10'

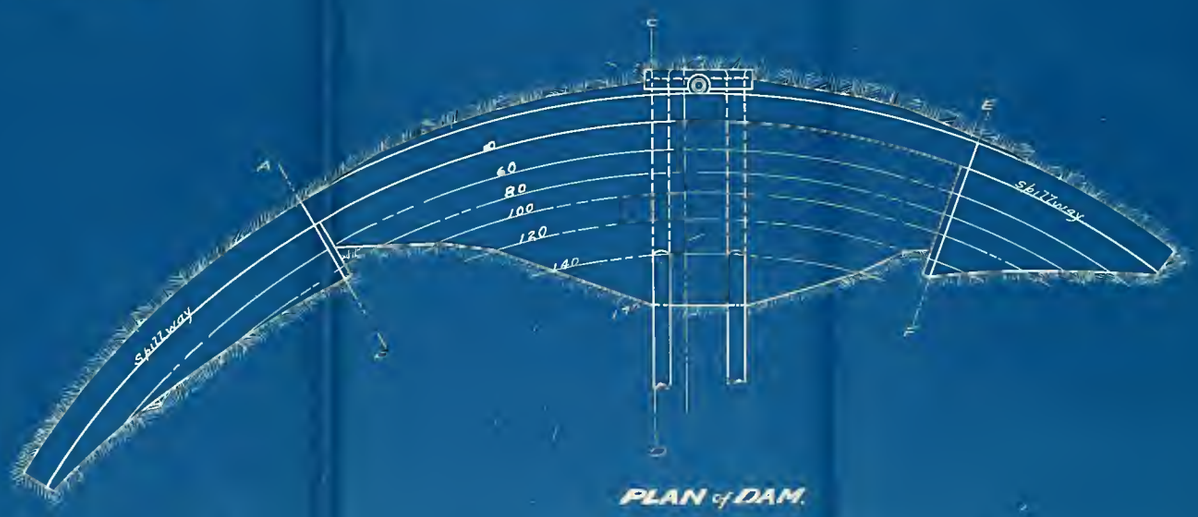


N A-B.



PROFILE of ELEVATION.

SCALE GIVEN



PLAN of DAM.

SCALE 1" = 80'

PROPOSED
HYDRO-ELECTRIC DEVELOPMENT
ON
NORTH PLATTE RIVER

DRAWN BY HFR. CHECKED BY HCJ

TRACED BY GHA

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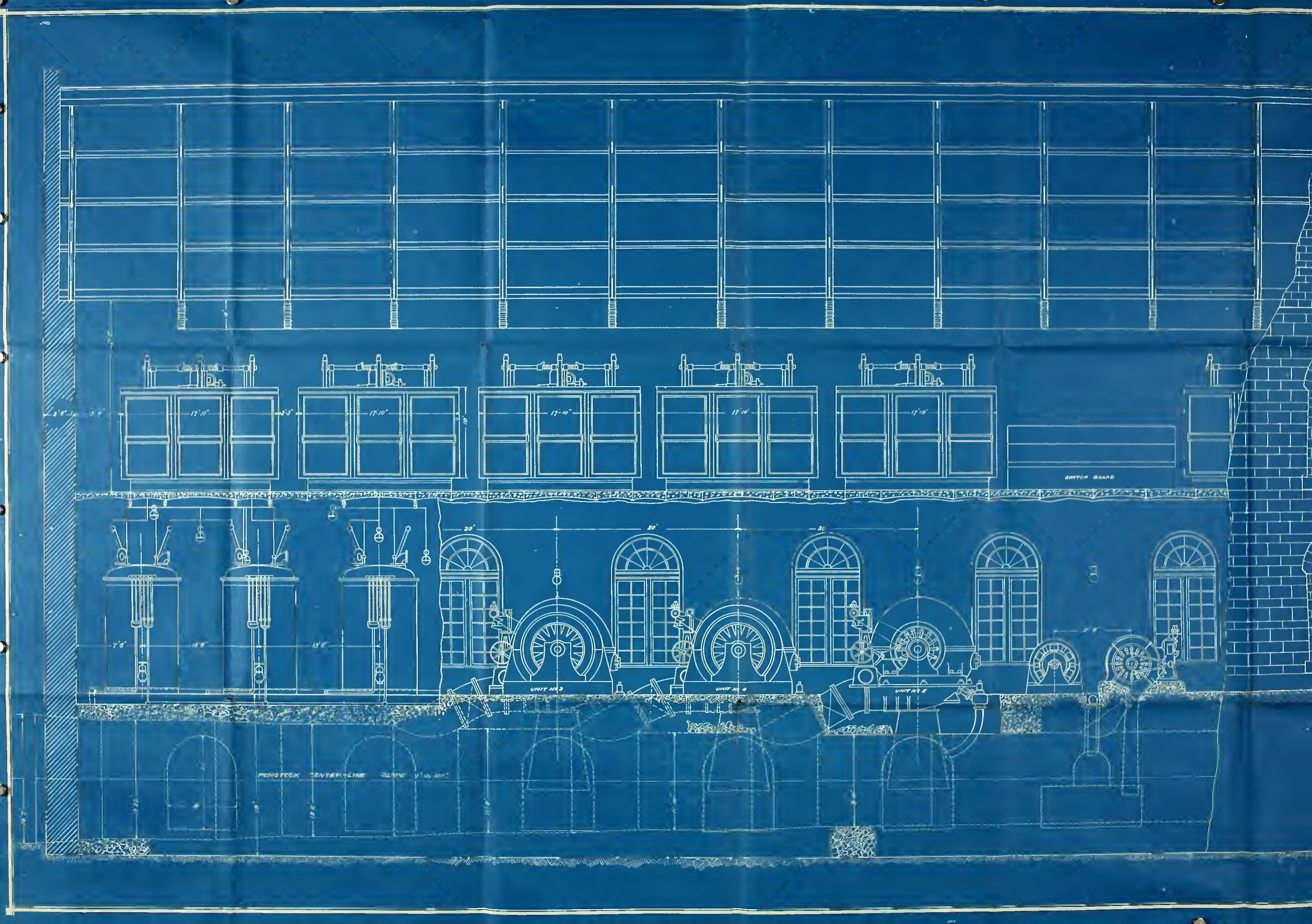
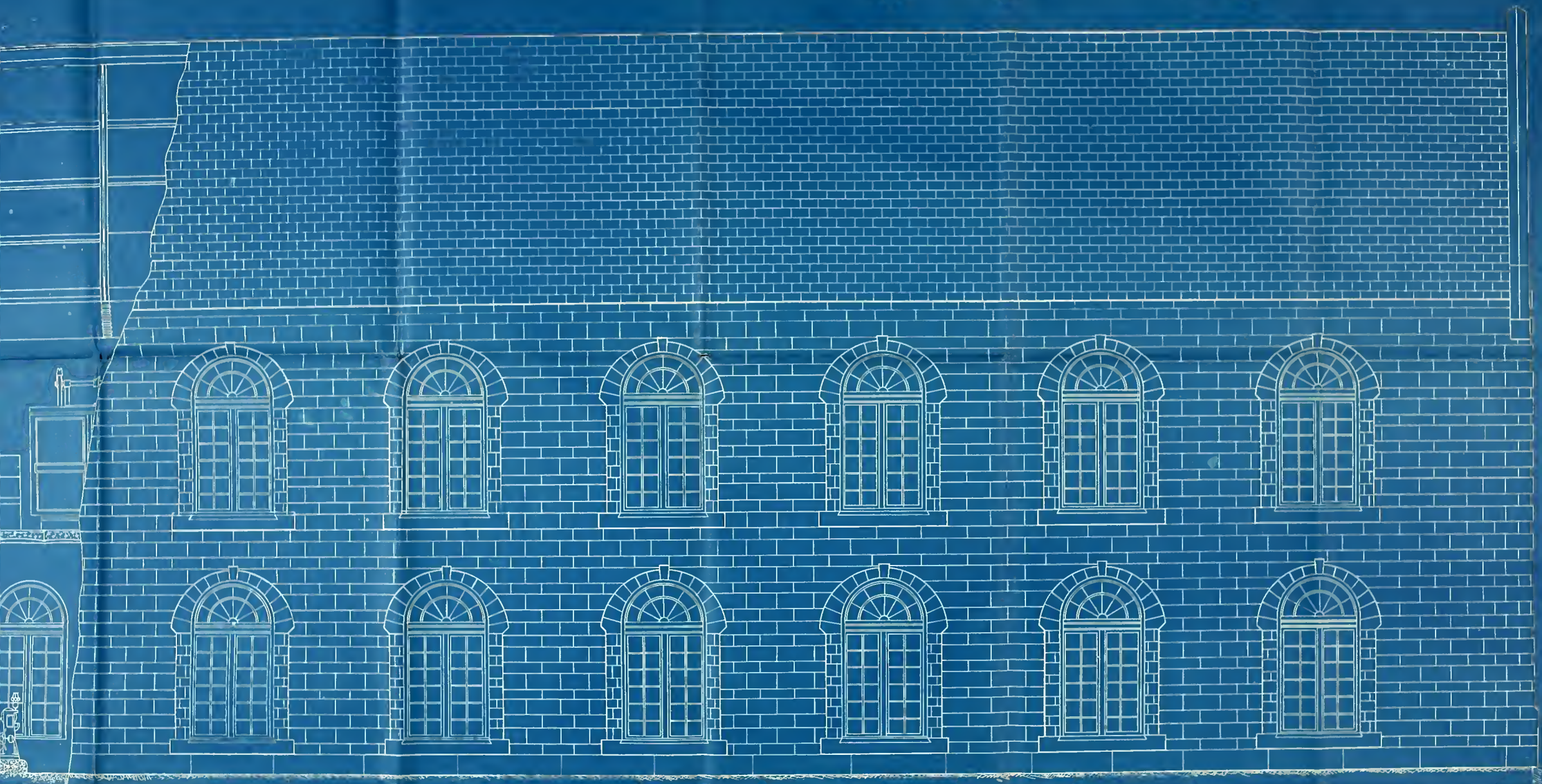
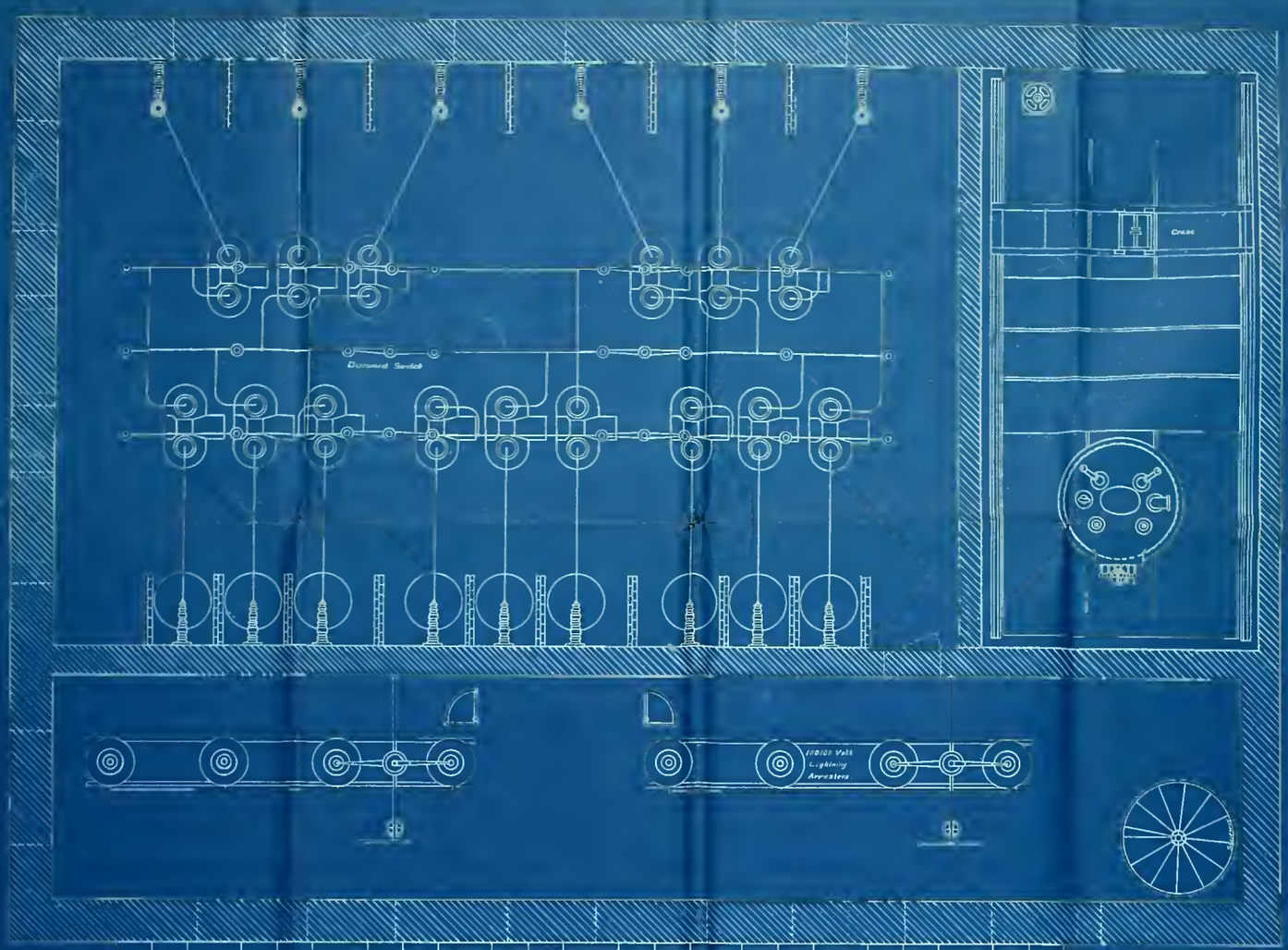
CHICAGO ILL. MAY 24 1912

DAM


17'-10"
17'-10"
17'-10"
17'10"
17'10"
SWITCH BOARD
20'
20'
20'
UNIT NO 3
UNIT NO 4
UNIT NO 5
PENSTOCK CENTER LINE SLOPE

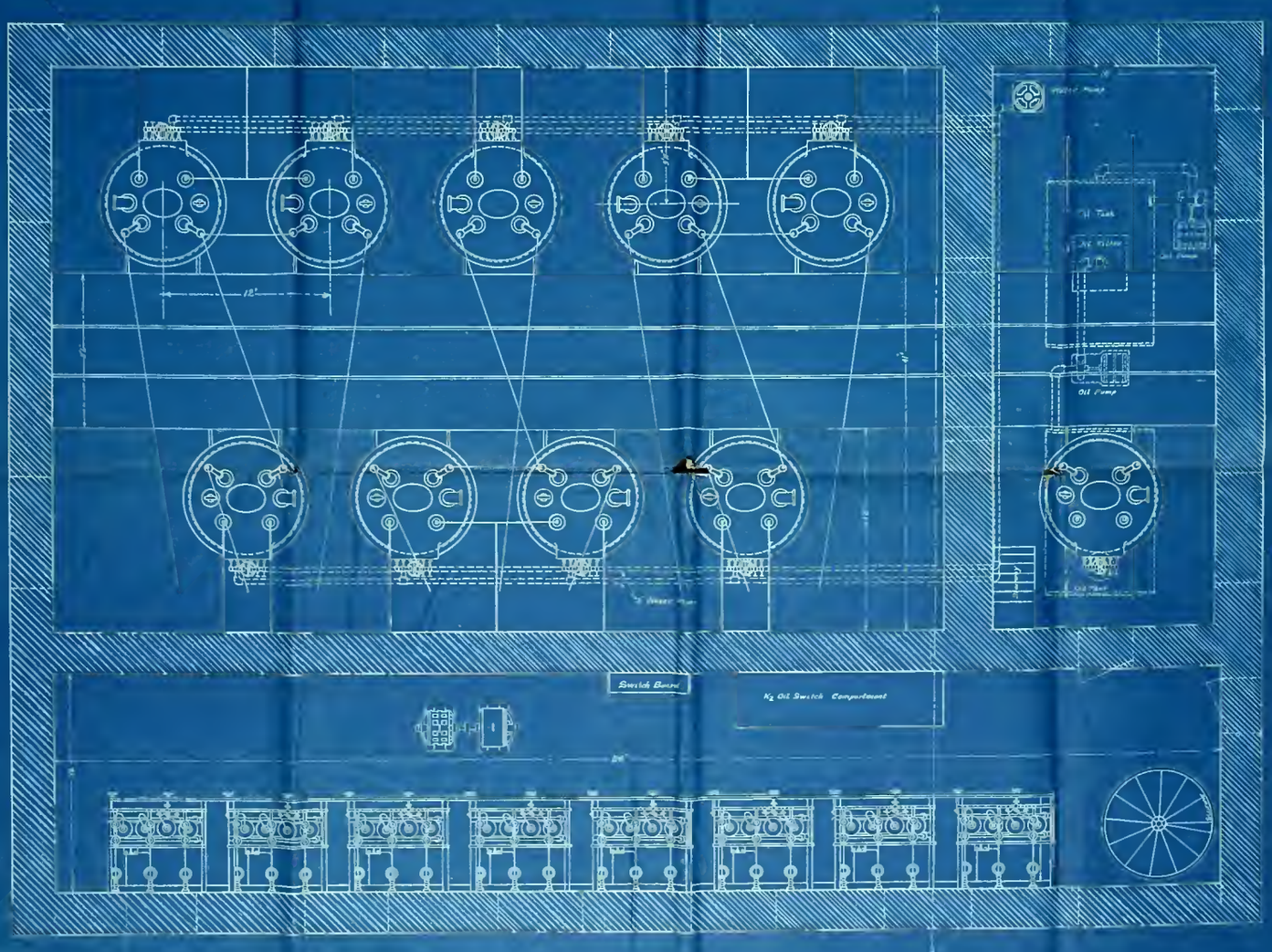


PROPOSED
HYDRO-ELECTRIC DEVELOPMENT
ON
NORTH PLATTE RIVER
DRAWN BY E.E. CHECKED BY R.C.D.
TRACED BY F.J.
ARMOUR INSTITUTE OF TECHNOLOGY
CHICAGO ILL. MAY 24 1912
POWER HOUSE, SECTION A-B.
SCALE 1" = 1FT



Outgoing Feeder Leads

PLAN OF SECOND FLOOR



PLAN OF FIRST FLOOR

Battery
Oil Pump
Crane

Low Tension Bus Compartment
Oil Switches
High Tension Bus-bars
Transformer Cells
SECTION THROUGH AA

PROPOSED
HYDRO-ELECTRIC DEVELOPMENT
ON
NORTH PLATTE RIVER.
DRAWN BY CAD. CHECKED BY
TRACED BY CAD
ARMOUR INSTITUTE OF TECHNOLOGY
CHICAGO, ILL. MAY 24, 1912 SCALE
TERMINAL STATION.